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# ARMY INDEPENDENT RISK ASSESSMENT GUIDEBOOK

**APRIL 2014**

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**US ARMY MATERIEL SYSTEMS ANALYSIS ACTIVITY**
**ABERDEEN PROVING GROUND, MARYLAND 21005-5071**

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This report presents the US Army's approach to Risk Assessments for Army Acquisition programs, with a focus on Technical and Schedule Risk. This report addresses in detail the complete breadth of Technical and Schedule Risk Assessment methodologies employed in the conduct of these Risk Assessments, to include the Quick-Turn and Full simulation-based Technical Risk Assessments, as well as the estimation-based Quick-Turn Schedule Risk Assessment and the analogous program-based Schedule Risk Data Decision Methodology. A Software Risk Assessment methodology is also presented. Examples are provided for all approaches.

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## LIST OF ACRONYMS

| | |
|---|---|
| AAR | - After Action Review |
| ACAT | - Acquisition Category |
| ALU | - Army Logistics University |
| AMRDEC | - Aviation and Missile Research Development and Engineering Center |
| AMSAA | - US Army Materiel Systems Analysis Activity |
| AoA | - Analysis of Alternatives |
| ARCIC | - Army Capabilities Integration Center |
| ARDEC | - Armament Research Development and Engineering Center |
| ARL | - Army Research Laboratory |
| ASD(R&E) | - Assistant Secretary of Defense for Research and Engineering |
| ATEC | - Army Test and Evaluation Command |
| BCA | - Business Case Analysis |
| C | - Consequence Level |
| C-BA | - Cost Benefit Analysis |
| CDD | - Capability Development Document |
| CDF | - Cumulative Density Function |
| CI | - Confidence Interval |
| CKB | - Capabilities Knowledge Base |
| CMMI | - Capability Maturity Model Integration |
| COCOMO | - Constructive Cost Model |
| DAMIR | - Defense Acquisition Management Information Retrieval |
| DASA R&T | - Deputy Assistant Secretary of the Army for Research & Technology |
| DAU | - Defense Acquisition University |
| DCARC | - Defense Cost and Resource Center |
| DCO | - Defense Connect Online |
| DOD | - Department of Defense |
| DODI | - Department of Defense Instruction |
| DOT&E | - Director of Operational Test & Evaluation |
| DTIC | - Defense Technical Information Center |
| ECP | - Engineering Change Proposal |
| EMD | - Engineering and Manufacturing Development |
| ERDC | - Engineer Research and Development Center |
| EVM | - Earned Value Management |
| GAO | - US Government Accountability Office |
| GCS | - Ground Combat System |
| GCV | - Ground Combat Vehicle |
| HQDA | - Headquarters, Department of the Army |

| | |
|---|---|
| ICD | - Initial Capabilities Document |
| IPT | - Integrated Product Team |
| IRL | - Integration Readiness Level |
| IRT | - Independent Review Team |
| | |
| KPP | - Key Performance Parameter |
| KSA | - Key System Attribute |
| KT | - Key Technology |
| | |
| L | - Likelihood |
| | |
| MDA | - Milestone Decision Authority |
| MDAP | - Major Defense Acquisition Program |
| MRL | - Manufacturing Readiness Level |
| MS | - Milestone |
| | |
| O&S | - Operations and Support |
| ODASA-CE | - Office of the Deputy Assistant Secretary of the Army for Cost & Economics |
| OSD | - Office of the Secretary of Defense |
| OSD-CAPE | - Office of the Secretary of Defense for Cost and Program Evaluation |
| | |
| PEO | - Program Executive Office |
| PM | - Project Manager |
| | |
| RDEC | - Research, Development, and Engineering Center |
| RDECOM | - Research, Development, and Engineering Command |
| RFI | - Request for Information |
| RFP | - Request for Proposal |
| | |
| SAR | - Selected Acquisition Report |
| SLOC | - Source Lines of Code |
| SME | - Subject Matter Expert |
| SRDDM | - Schedule Risk Data Decision Methodology |
| | |
| TARDEC | - Tank Automotive Research, Development, and Engineering Center |
| TMA | - Technology Maturity Assessment |
| TRA | - Technology Readiness Assessment |
| TRAC | - US Army Training and Doctrine Command (TRADOC) Analysis Center |
| TRADOC | - US Army Training and Doctrine Command |
| TRL | - Technology Readiness Level |
| | |
| WBS | - Work Breakdown Structure |
| WSARA | - Weapon Systems Acquisition Reform Act |

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# ARMY INDEPENDENT RISK ASSESSMENT GUIDEBOOK

## 1. EXECUTIVE SUMMARY

**1.1 Summary.** In May 2009, the Weapon Systems Acquisition Reform Act (WSARA) was signed into law to reduce waste in defense spending by reforming the way in which the Pentagon contracts and purchases major weapon systems. As a result, WSARA is driving more analysis to support the Analysis of Alternatives (AoA) and other major acquisition studies. In response, the US Army Materiel Systems Analysis Activity (AMSAA) served as the lead organization on an Army Risk Integrated Product Team (IPT), which was established at the direction of Senior Army analysis leaders, to develop standard methodologies for assessing technical, schedule, and cost risk as part of acquisition studies. The risk assessments are intended to inform decision makers of the potential risks associated with each alternative in the study. AMSAA led the development and application of technical and schedule risk assessment methodologies, and the Office of the Deputy Assistant Secretary of the Army for Cost & Economics (ODASA-CE) led the development and application of the cost risk and uncertainty analysis methodology.

The purpose of this guidebook is to document the current state of these methodologies. This guidebook differs from the Risk Management Guide for DOD Acquisition, because the Army Risk IPT methodology is focused on independent risk assessments that are conducted at a specific moment in time and incorporate forecasting.[1] The Risk Management Guide for DOD Acquisition is used to assist Project Managers (PMs), program offices, and IPTs in effectively managing program risks during the entire acquisition process, including sustainment.

The technical risk assessment methodology measures the risk that a technology relevant to an Army acquisition system is not sufficiently developed (i.e., technology matured, integration characterized, and manufacturing processes matured) within the desired timeframe. Technical risk is reported as three levels (low, moderate, high) based on the standard Department of Defense (DOD) Risk Reporting Matrix for Acquisition. The risk level is determined by likelihood (probability) and consequence of event occurrence. Two approaches have been developed for assessing technical risk, based on the amount of time available to complete the assessment; these are referred to as the full approach and the quick-turn approach. The full approach is a semi-quantitative assessment of the risk to sufficiently developing each key technology within predetermined time constraints. It is based on the probability of the technology being sufficiently matured, integrated, and manufacturable within the required timeframes. AMSAA conducts a risk workshop to gather the required inputs to support the full approach. The workshop is a critical part of the risk assessment process, and brings together representatives from across the acquisition community. The quick-turn approach is a qualitative assessment of the risk to sufficiently developing each key technology within predetermined time constraints. It is based on the current technology, integration, and manufacturing readiness levels, and the qualitative risk rating for any identified technical risks for each key technology. The appropriate Research, Development, and Engineering Center (RDEC) conducts a risk workshop to review SME input to support the quick-turn approach.

[1] Risk Management Guide for DOD Acquisition, Sixth Edition, Department of Defense, August 2006.

The schedule risk assessment methodology measures the likelihood that each system alternative will meet a program's estimated schedule, based on historical analogous programs. Two approaches have been developed for assessing schedule risk, based on the amount of historical analogous programs and associated schedule data; these are referred to as the full approach and the quick-turn approach. The full approach utilizes phase-level (e.g., Engineering and Manufacturing Development Phase) acquisition times from historical analogous programs to conduct quantitative modeling using Monte Carlo simulation and other mathematical techniques. Results of the quantitative modeling yield a probability of meeting the program schedule. The quick-turn approach qualitatively utilizes phase-level historical data, when there are not enough programs or available data to have confidence in quantitative modeling results. Schedule risk is reported as three levels (low, moderate, high), based on the results of the full or quick-turn approach.

Cost risk and uncertainty analysis identifies the cost, in terms of dollars, time, and materials that should be added to a point estimate to increase the probability of meeting the desired outcome. It estimates the resources required to meet specified requirements and performance objectives. Without risk analysis, a cost estimate will usually be a single value, called a point estimate, which does not account for the uncertainties inherent in the effort. Cost risk and uncertainty analysis communicates to decision makers the degree to which specific uncertainties contribute to overall cost and schedule risk. The cost risk and uncertainty analysis methodology has been documented by ODASA-CE in a Draft US Army Cost Analysis Handbook.[2] The methodology has been applied and accepted within the analytical community. The cost risk methodology is not included in this guidebook; reference the cost analysis handbook if further details are desired.

In order to meet the organization's risk assessment demands, AMSAA established a permanent Risk Team in October 2011. To date, the AMSAA Risk Team has completed 12 technical and schedule risk assessments to support AoAs and Cost-Benefit Analyses (C-BAs). AMSAA also developed a software risk assessment methodology, which was used to support a software-focused AoA. Lessons learned from these applications have contributed to methodology and process improvements. The AMSAA Risk Team will continue to engage the Risk IPT as needed, as major methodology efforts occur. In addition, the AMSAA Risk Team continues to socialize and improve these methodologies based on stakeholder feedback.

Two key related areas for further development include risk interdependencies and risk-informed trade space analysis. The Risk IPT recognizes that there are interdependencies between technical, schedule, and cost risks. The current schedule risk assessment methodology does not support inclusion of the technical risk assessment outputs. The AMSAA Risk Team is currently developing an event-level schedule risk assessment methodology, which will model key events within each acquisition phase. This new methodology will allow inclusion of the technical risk assessment outputs, as well as support the ability to conduct trades. For example, if an alternate technology is considered in order to reduce technical risk, the schedule risk methodology will have the ability to model how it affects the schedule. In addition, AMSAA has been collaborating with ODASA-CE regarding inclusion of the technical and schedule risks into their cost risk analysis. This guidebook will be updated as necessary to document major

[2] US Army Cost Analysis Handbook, ODASA-CE, February 2010.

methodology changes.  Recommended approaches and guidelines are provided in this guidebook; however, they may need to be tailored as applicable for unique studies.

## 2. INTRODUCTION

**2.1 Preface.** As acquisition schedules accelerate and budgets tighten, Army leadership needs an early, independent, and agile approach for assessing risk and making difficult program decisions. The risk assessment methodology documented in this guidebook was developed to provide leadership with the essential information required to make informed decisions at major milestones, and adheres to existing policy. The WSARA of 2009 is driving more analysis to support AoAs, of which risk assessments and trade-offs are key elements.[3] Department of Defense Instruction (DODI) 5000.02 also provides guidance related to risk assessments and AoAs.[4] Guidance from these sources was incorporated during the development of this risk assessment methodology.

This guidebook differs from the Risk Management Guide for DOD Acquisition, because the Army Risk IPT methodology is focused on independent risk assessments that are conducted at a specific moment in time and incorporate forecasting.[5] The Risk Management Guide for DOD Acquisition is used to assist PMs, program offices, and IPTs in effectively managing program risks during the entire acquisition process, including sustainment.

**2.2 Background.** AMSAA hosted an Army Risk Assessment Workshop in February 2011 to organize and plan the Army's effort to develop methodologies and establish capabilities to conduct risk assessments for Army acquisition programs. The objectives of the meeting included the following: gain a common understanding of risk terminology; share current methods used to perform risk assessments; identify risk assessment capabilities needed for future AoAs; and determine capability gaps in performing risk assessments. DODI 5000.02 and WSARA of 2009 were reviewed to gain a common understanding of risk-related policy for AoAs. Existing risk methodologies and lessons learned from recent AoAs were shared and discussed.

Following the workshop, an AMSAA-led Army Risk IPT was formed in March 2011 to advance the development of risk assessment methodologies for acquisition studies. Upon its establishment, the IPT had representatives from the following organizations: the Office of the Deputy Assistant Secretary of the Army for Cost & Economics (ODASA-CE), U.S. Army Training and Doctrine Command (TRADOC) Analysis Center (TRAC), Army Capabilities Integration Center (ARCIC), Tank Automotive Research, Development and Engineering Center (TARDEC), Program Executive Office for Ground Combat Systems (PEO GCS), Project Manager for Ground Combat Vehicle (PM GCV), Engineer Research and Development Center (ERDC), and Army Logistics University (ALU). Since March 2011, representatives from other RDECs have joined the Risk IPT, and a few of the organizations no longer actively participate.

Leadership guidance from the Army Risk Assessment Workshop included developing quantitative and repeatable methodologies that incorporate historical data. The IPT researched and reached out to fellow Army organizations, Joint Services, industry, and academia to understand and incorporate elements of their risk assessment methodologies. The IPT also held

[3] Weapon Systems Acquisition Reform Act of 2009, Public Law 111-23, May 22, 2009.
[4] Department of Defense Instruction, Number 5000.02, Under Secretary of Defense for Acquisition, Technology, & Logistics (USD(AT&L)), December 8, 2008.
[5] Risk Management Guide for DOD Acquisition, Sixth Edition, Department of Defense, August 2006.

informal consultations with representatives from the Office of the Secretary of Defense for Cost and Program Evaluation (OSD-CAPE), Assistant Secretary of Defense for Research and Engineering (ASD(R&E)), Defense Acquisition University (DAU), and other key stakeholders in the acquisition process to obtain feedback during the methodology development process and initial application of the methodologies.

## 3. KEY DEFINITIONS, TERMS, AND PRINCIPLES

**3.1 Technical Risk.** Technical risk is defined as the risk that a technology relevant to an Army Acquisition system is not sufficiently developed (i.e., technology matured, integration characterized, and manufacturing processes matured) within the desired timeframe.

Technical risk is reported at three levels (low, moderate, and high) based on the standard DOD Risk Reporting Matrix for Acquisition.[6] The risk level is determined by likelihood (probability) and consequence of event occurrence. Two approaches (full and quick-turn) have been developed for assessing technical risk based on the amount of time and information available to complete the assessment.

**3.1.1 Full Approach.** The full technical risk assessment approach is a semi-quantitative assessment of the risk to sufficiently developing each Key Technology (KT) within predetermined time constraints. It is based on the probability of the technology being sufficiently matured, integrated, and manufacturable within the required timeframe. The probabilities are based on Subject Matter Expert (SME) input and forecasts, or historical data. AMSAA conducts a risk workshop to review SME input to support the full approach.

**3.1.2 Quick-Turn Approach.** The quick-turn technical risk assessment approach is a qualitative assessment of the risk to sufficiently developing each KT within predetermined time constraints. It is based on the current Technology Readiness Level (TRL), Integration Readiness Level (IRL) and Manufacturing Readiness Level (MRL), and the qualitative risk rating for any identified technical risks for each KT. The appropriate RDEC conducts a risk workshop to review SME input to support the quick-turn approach.

**3.1.3 Data Resolution.** The technical risk assessment requires the following data:

- KTs for each alternative system.
- Current readiness level assessments for each alternative KT: TRL, IRL, and MRL. Each of these readiness levels is explained below in sections 3.5 – 3.7.
- Estimated transition times for each technology to reach predetermined readiness levels. For example:
    - TRL 6 (system prototype demonstrated to meet specific performance criteria in a relevant environment), IRL 6 (integration element baseline established that identifies all required interfaces), and MRL 6 (ability to produce prototype in a production relevant environment with prototype manufacturing processes, technologies, materials, tools, and personnel) by the planned milestone (MS) B date.
    - TRL 7 (system prototype demonstrated to meet specific performance criteria in an operational environment), IRL 8 (functionality of integration technology has been demonstrated in prototype modified vehicles that all system to system interface requirements have been defined and functionally qualified), and MRL 8 (pilot line

[6] Risk Management Guide for DOD Acquisition, Department of Defense, August 2006.

capability demonstrated in producing the detailed design of product features - ready to begin low rate production) by the planned MS C date.

- A technology or system is not sufficiently developed when it does not meet the technical and manufacturing requirements acceptance criteria within the desired timeframe. The total set of requirements and their acceptance criteria for each technology, subsystem or system must be established and verified either by test, analysis or inspection. If these requirements are not verified, SMEs must provide rationale on how the requirement criteria are met. If no rationale is provided then this will be identified as a technical risk.

These transition times are based on SME input or historical technology development data. Eliciting SME input for transition times may be done through a risk questionnaire.

- Specific technical risks for each technology are identified, to include an assessed risk rating. These risks may be referenced in transition time estimates. An example of a specific moderate technical risk for an upgraded diesel engine is shown in Table 1 below, where C reflects consequence level and L reflects likelihood level. Likelihood and consequence levels are further discussed in Section 3.911.

**Table 1. Specific Technical Risk Example**

| Technology | Risk Title | Description | Context | Consequence if Realized | C | L | Risk Rating |
|---|---|---|---|---|---|---|---|
| **Upgraded Diesel Engine** | Selection of Front End Accessory Drives (FEAD) Design | If the current FEAD design is used instead of a redesigned FEAD, then there may be engine overheating and vehicle mission failures. | Manufacturer of the upgraded diesel engine proposes a FEAD design that has not been tested in the vehicle and failure of this can lead to engine overheating and vehicle mission failures. | Engine overheating and vehicle mission failures. | **4** | **2** | Moderate |

**3.2 Schedule Risk.** Schedule risk is defined as the likelihood that each system alternative will meet a program's estimated schedule milestones, based on historical analogous program data. Schedule risks are reported at three levels (low, moderate, or high) and are based on the results of AMSAA's full or quick-turn schedule risk assessments.

**3.2.1 Full Approach.** The full schedule risk assessment approach is a quantitative assessment conducted for each alternative within the acquisition study. A probability is assessed for completing a given phase (e.g., Engineering and Manufacturing Development (EMD) phase) within the schedule developed by the PM, based upon historical analogous program data. A risk rating is assigned to each alternative based upon the calculated probability.

**3.2.2 Quick-Turn Approach.** The quick-turn schedule assessment risk approach is a qualitative assessment comparing each alternative's proposed schedule to historical analogous programs by acquisition lifecycle phase. A qualitative risk rating is assigned to each alternative based upon comparison to historical averages, known schedule delays for historical analogous programs, SME input, and technical risk assessment results. This type of schedule risk assessment is primarily driven by historical data limitations and time constraints based on completion date of the study.

**3.2.3 Data Resolution.** The schedule risk assessment requires the following data:

- Program schedule for each alternative system.
- Historical analogous programs:
  - Length (in months) of each acquisition phase.
  - Schedule delays that occurred within each phase.

**3.3 Cost Risk.** Cost risk and uncertainty analysis identifies the cost, in terms of dollars, time, and materials that should be added to a point estimate to increase the probability of meeting the desired outcome. The analysis produces estimates of the resources required to meet specified requirements and performance objectives. Without risk analysis, a cost estimate will usually be a single value, called a point estimate, which does not account for the uncertainties inherent in the effort. Cost risk and uncertainty analysis communicates to decision makers the degree to which specific uncertainties contribute to overall cost and schedule risk. Ignoring potential uncertainties can cause underfunding, cost overruns, and the reduction of a program's scope or necessitation of additional funding to meet objectives. For more information on cost risk, refer to the US Army Cost Analysis Handbook.[7]

**3.4 Risk Assessments vs. Risk Management.** Both risk assessments and risk management are key processes used to evaluate risk on systems. The processes help to ensure program cost, schedule, and performance objectives are achieved throughout the acquisition life cycle. There are fundamental differences between the purposes of each process, which are highlighted in this section.

Risk assessments should be performed by independent organizations (i.e., organizations not under the management of the program office and not involved in the development of technologies related to the program) at fixed points in time, usually early in the acquisition process, to advise decision makers of potential risks among the alternatives under consideration. The assessments also support trade space analysis and requirements development. Although risk assessments are conducted at a point in time, the methodology incorporates forecasting and projection to make predictions about future outcomes. The results of risk assessments are also provided to the associated PMs for their awareness and input to the risk management process.

In contrast, risk management is a continuous process used to manage uncertainties throughout the life cycle of a system. Risk Management more broadly considers all aspects of a program, such as operational needs, attributes, constraints, performance parameters, threats, technology, design processes, etc. An effective process requires involvement of the entire program team and also requires help from outside experts knowledgeable in critical risk areas. The Risk Management Guide for DOD Acquisition documents the process for PMs, program offices, and IPTs to effectively manage program risks throughout the acquisition process.

[7] US Army Cost Analysis Handbook, ODASA-CE, February 2010.

The risk management process model, as shown in Figure 1, includes the following key activities, performed on a continuous basis:

- Risk Identification,
- Risk Analysis,
- Risk Mitigation Planning,
- Risk Mitigation Plan Implementation, and
- Risk Tracking.

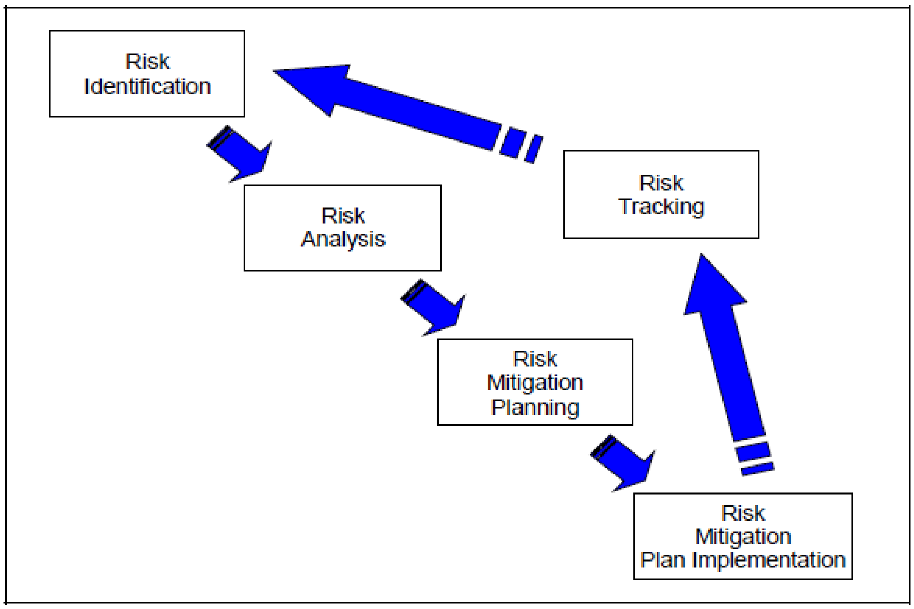


**Figure 1. DOD Risk Management Process**

**3.5 Technology Readiness Level.** TRL is a systematic metric/measurement system used by government agencies, including the DOD, to support assessment of the maturity of a particular technology as well as the comparison of maturity between different types of technologies.

APPENDIX A –contains the definitions for each TRL (1-9), along with questions that can be used to aid in TRL assessment.

TRLs should be assessed according to DOD Technology Readiness Assessment (TRA) Guidance dated April 2011.[8] When possible, the technical risk assessment should rely on KT determination and readiness level assessments done as part of the TRA. This may be possible for pre-MS B AoAs, but will require additional assessment of MRL and IRL for each technology. The same SMEs used in the TRA should be consulted to assess the MRL and IRL, if available. If unavailable, then other independent SMEs can make the assessments.

When the technical risk assessment cannot be coordinated with a TRA (e.g., pre-MS A AoAs), an informal Technology Maturity Assessment (TMA) must be completed. The TMA

[8] Department of Defense Technology Readiness Assessment (TRA) Guidance, Office of the Assistant Secretary of Defense for Research and Engineering (ASD (R&E)), April 2011.

must be coordinated with the PM and the applicable RDEC to ensure appropriate SMEs are assigned to the assessment. The preferred process is for the applicable RDEC (e.g., TARDEC for ground systems, AMRDEC for aviation systems) to lead the TMA following the general guidelines of the Army TRA Guidance. TMA results will be reviewed at a risk workshop to reach group consensus on assessed levels.

**3.6 Integration Readiness Level.** IRL is a systematic measurement of the level of integration between a technology and the environment into which it will operate. The environment consists of various physical systems (electrical, mechanical, hydraulic, informational, etc.), other technologies, functional groups such as manufacturing and service, regulations, military standards, test environments, etc. Adequate interfaces between the technology and environment are required to meet overall system performance requirements. The IRL provides an indicator of the level of accountability of these interfaces affecting technology implementation. IRL is not yet an approved DOD measure. Definitions for IRLs were developed by the Stevens Institute of Technology for systems interoperability determinations, and modifications were made by TARDEC for use in Army Risk Assessments.[9] AMSAA and TARDEC are currently socializing IRLs in the acquisition community with the intent of achieving DOD approval.

APPENDIX B –contains the definitions for each IRL (1-9), along with questions that can be used to aid in IRL assessment.

**3.7 Manufacturing Readiness Level.** MRL is a systematic measurement used by government agencies, including the DOD, to assess the maturity of a given technology, component, or system from a manufacturing perspective prior to incorporating that technology into a system or subsystem.

APPENDIX C –contains the definitions for each MRL (1-10), along with questions that can be used to aid in MRL assessment.

In addition, the MRL Deskbook provides official guidance on using MRLs in support of Risk Assessments.[10]

**3.8 Performance Assessment.** The performance assessment, which considers item-level, system-level, and operational effectiveness, is a key analysis effort supporting the AoA and other acquisition studies. AMSAA is typically tasked with providing the item and system-level performance data and analyses for these studies, which estimate the performance of alternatives across several functional areas (e.g., force protection, survivability, lethality, mobility, sustainment, target acquisition, fuel consumption, etc.) for a wide variety of environmental and operating conditions. The item and system-level data is typically provided to TRAC to support the operational effectiveness modeling and analysis. Like the risk assessment, the performance assessment can also be used to inform trade space analysis and requirements

[9] Brian Sauser, et al. "Integration Maturity Metrics: Development of an Integration Readiness Level." Journal of Information Knowledge Systems Management, Volume 9, No. 1 (January 2010): 17-46.

[10] Manufacturing Readiness Level (MRL) Deskbook – Version 2.2, OSD Manufacturing Technology Program in conjunction with The Joint Service/ Industry MRL Working Group, July 2012

development. The risk assessments and performance assessment should be coupled together to give the decision maker a complete understanding of potential risks and performance capabilities, so that accurate conclusions are made.

**3.9 Risk Reporting Matrix.** A standard format for evaluating and reporting risk as a function of the likelihood and consequence of occurrence helps ensure common understanding of risks at all levels. The Risk Reporting Matrix in Figure 2 below is the DOD standard established in the Risk Management Guide for DOD Acquisition.[11] The matrix is used to determine the level of each risk, and is reported as low (green), moderate (yellow), or high (red).

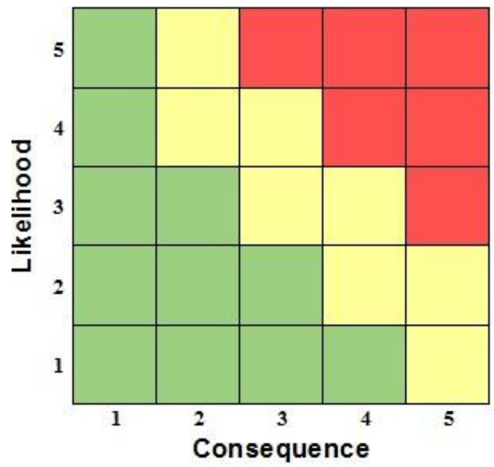


**Figure 2. Risk Reporting Matrix**

Likelihood is the probability that an undesirable event will occur. The level of likelihood is established using specified criteria shown in Table 2 below. For example, if an event has an estimated 70% probability of occurrence, the corresponding likelihood level is 4.

**Table 2. Likelihood Level Criteria**

| Level | Likelihood | DOD Guidance[10] | Probability of Occurrence |
|---|---|---|---|
| 1 | Not Likely | ~ 10% | L <= 20% |
| 2 | Low Likelihood | ~ 30% | 20% < L <= 40% |
| 3 | Likely | ~ 50% | 40% < L <= 60% |
| 4 | Highly Likely | ~ 70% | 60% < L <= 80% |
| 5 | Near Certainty | ~ 90% | L > 80% |

Consequence is the impact (severity) if the undesirable event occurs. The level and types of consequences are established using criteria such as those shown in Table 3. Risk consequences include decreased technical performance, delays to schedule, and increased cost. The consequence level definitions may be tailored for a specific application. Continuing with the prior example of an event with 70% probability of occurrence, if the same event is determined to have a minor reduction in technical performance, then the corresponding consequence level is 2.

[11] Risk Management Guide for DOD Acquisition, Department of Defense, August 2006.

## Table 3. Consequence Level Criteria[12]

| Level | Technical Performance | Schedule | Cost |
|---|---|---|---|
| 1 | Minimal consequences to technical performance but no overall impact to the program success. | Negligible schedule slip. | Pre-MS B: <= 5% increase from previous cost estimate.<br>Post MS B: limited to <= 1% increase in Program Acquisition Unit Cost (PAUC) or Average Procurement Unit Cost (APUC). |
| 2 | Minor reduction in technical performance or supportability, can be tolerated with little or no impact on program success. | Schedule slip, but able to meet key dates (e.g., PDR, CDR, FRP, FOC) and has no significant impact to slack on critical path. | Pre-MS B: > 5% to 10% increase from previous cost estimate.<br>Post MS B: <= 1% increase in PAUC/APUC with potential for further cost increase. |
| 3 | Moderate shortfall in technical performance or supportability with limited impact on program success. | Schedule slip that impacts ability to meet key dates (e.g., PDR, CDR, FRP, FOC) and/or significantly decreases slack on critical path. | Pre-MS B: > 10% to 15% increase from previous cost estimate.<br>Post MS B: > 1% but < 5% increase in PAUC/APUC |
| 4 | Significant degradation in technical performance or major shortfall in supportability with moderate impact on program success. | Will require change to program or project critical path. | Pre-MS B: > 15% to 20% increase from previous cost estimate.<br>Post MS B: >= 5% but <10% increase in PAUC/APUC |
| 5 | Severe degradation in technical/supportability threshold performance; will jeopardize program success. | Cannot meet key program or project milestones. | Pre-MS B: > 20% increase from previous cost estimate.<br>Post MS B: >= 10% increase in PAUC/APUC danger zone for significant cost growth and Nunn-McCurdy breach) |

The corresponding likelihood and consequence levels are plotted on the Risk Reporting Matrix to determine the level of risk. In the example above, a likelihood level of 4 and consequence level of 2 equates to a moderate technical risk (yellow) rating.

[12] Risk Management Guide for DOD Acquisition, Department of Defense, August 2006.

# 4. RISK ASSESSMENTS FOR ARMY ACQUISITION STUDIES

**4.1 Process.** The general process for conducting risk assessments for acquisition studies is shown in Figure 3. Note that this process flow is based on executing the full technical and schedule risk assessment approaches. The basic process steps include gathering and conducting baseline information/analysis, quantifying risks, highlighting risk drivers, and identifying mitigations.

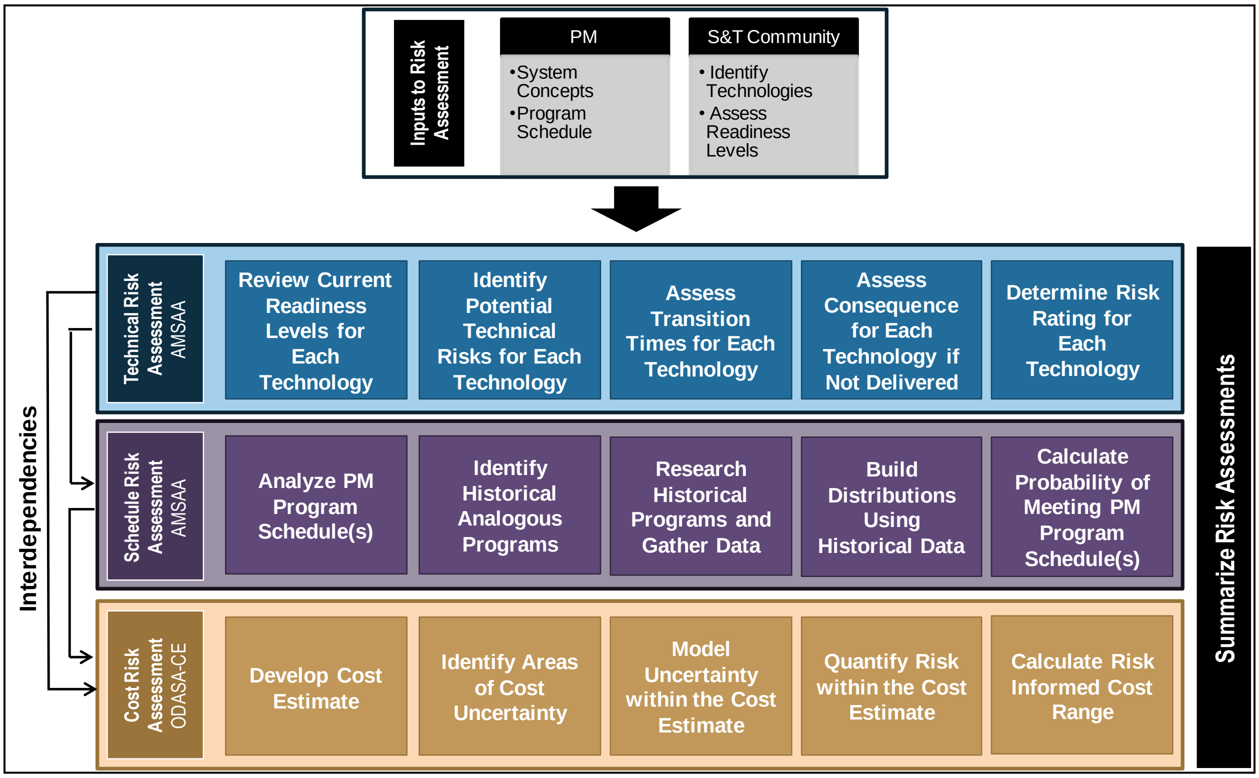


**Figure 3. Army Independent Risk Assessment Process Flow**

AMSAA is responsible for conducting the technical and schedule risk assessments. ODASA-CE is often responsible for conducting the cost risk assessment; however, for some acquisition studies, TRAC, AMSAA, or the PM is responsible for the cost assessment. The AMSAA risk analysts maintain communication with the cost analysts throughout the assessments to ensure common assumptions and information are shared. Details of the risk assessment process will be further discussed throughout the guidebook.

**4.2 Risk Workshop.** AMSAA conducts a risk workshop to facilitate the gathering of data to support the full technical, schedule, and cost risk assessment approaches. The workshop is a key part of the risk assessment process, and requires broad participation from study stakeholder organizations to ensure workshop success. All discussions and briefs are on a "non-attribution" and "not-for-release" basis to encourage dialogue and information sharing. Main objectives of the workshop include the following:

- Review and gain consensus on the current TRL, IRL, and MRL for each KT.
- Determine the technical risk rating for each KT:

    - Assess the transition times for each technology to reach the required TRL, IRL, and MRL.
    - Assess the consequence to performance, schedule, or cost if the technology is not sufficiently developed within the timeframe.
- Discuss PM schedule(s), gain consensus on analogous programs, and discuss schedule risks for each alternative to support the schedule risk assessment.
- Identify high risk areas and cost drivers for each alternative to support the cost risk assessment.

The workshop typically lasts one week, depending upon the number of study alternatives and KTs. Holding the workshop at a location that maximizes attendance will make the most of dialogue and information exchange. Telecon and Defense Connect Online (DCO) capability should be made available for participants that cannot attend. Read-ahead slides should be sent out to workshop attendees with administrative information, purpose and objectives, required participants and roles, workshop agenda, risk methodology overview, and other applicable data/information. A pre-workshop telecon with the risk workshop attendees will ensure the workshop purpose, roles/responsibilities, and required outputs are understood prior to the workshop. In addition, the telecon is a good opportunity to finalize any key assumptions regarding the readiness levels and to tailor the consequence definitions.

An experienced facilitator, with knowledge of the risk assessment methodologies, should lead the risk workshop to ensure study success. A data collection tool can assist in elicitation of the information, documentation and rationale, and post-processing following the workshop. A designated workshop participant should be assigned to document pertinent discussions. Following the workshop, an after action review (AAR) survey may be sent to participants to capture potential methodology or process improvements. Details on the recommended structure of the risk workshop are described in section 5.4.7.

## 5. TECHNICAL RISK ASSESSMENT

**5.1 Background.** DOD defines risk in acquisition programs as a measure of future uncertainties in achieving program performance goals and objectives within defined cost, schedule, and performance constraints. Risk has two components:

- Probability (or likelihood) of event occurrence.
- Consequence (or effect) of event occurrence.

The Army's independent technical risk assessment methodology uses the standard risk analysis approach established in the Risk Management Guide for DOD Acquisition.[13] The Risk Reporting Matrix in Figure 2 is the DOD standard used to determine the level of risks (low, moderate, high) identified within an acquisition program.

Senior Army and OSD leaders have requested increased quantitative emphasis in the standard DOD acquisition risk analysis method. The technical risk assessment described below follows this guidance by incorporating quantitative methods to capture uncertainties not captured with the standard DOD acquisition risk analysis method.

**5.2 Purpose.** The technical risk assessment measures the technology risks associated with an Army acquisition system in order to provide the following information to decision makers:

- Independent SME assessment of KTs and their readiness levels (TRL, MRL, and IRL), when risk assessment timing does not align with the formal TRA.
- Identification of technical risks associated with each KT and materiel solution.
- Insight into areas of mitigation necessary for each materiel solution included in the assessment.
- Early identification of high risk technologies.

**5.3 Quick-Turn Approach.** The quick-turn technical risk assessment approach is a qualitative assessment of the risk to sufficiently developing each KT within the predetermined time constraints. The assessment is based only on the current readiness levels (TRL, MRL, and IRL) and the qualitative risk rating for any identified technical risks for each KT. Independent SMEs should be used to assess the technology readiness levels and identify technical risks, to include a risk rating. The appropriate RDEC should be responsible for identifying appropriate technology SMEs, assessing the current readiness levels, identifying specific technical risks, and conducting a risk workshop to review SME evaluations of readiness levels and risk ratings assigned to each specified technical risk. APPENDIX D –contains sample readiness assessment guidance for RDECs to issue to SMEs.

The quick-turn approach is most applicable for Engineering Change Proposals (ECPs), C-BAs, Business Case Analyses (BCAs), and instances where turnaround time does not support execution of the full technical risk assessment.

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[13] Risk Management Guide for DOD Acquisition, Department of Defense, August 2006.

When conducting a quick-turn technical risk assessment, the overall technical risk for a given alternative is the risk level assigned to the highest-rated KT or risk element. Alternately, these KTs or elements may be binned in risk categories, with the alternative assigned a series of risk ratings based on the highest-rated element in each designated bin. After determining the technical risk for a given alternative, mitigation strategies are identified and residual risk is assessed. Table 4 shows notional quick-turn technical risk assessment results.

Note: Steps one through six of the full technical risk assessment (Section 5.4) also apply for the quick-turn approach.

**Table 4. Notional Quick-Turn Technical Risk Assessment Results**

| Key Technology | TRL | IRL | MRL | Technical Risk |
|---|---|---|---|---|
| Engine 1 | 5 | 5 | 4 | M |
| Engine 2 | 7 | 6 | 10 | L |
| Alternator | 6 | 5 | 4 | M |
| Double-V Hull | 9 | 9 | 10 | L |
| Suspension 1 | 9 | 9 | 10 | L |
| Suspension 2 | 5 | 4 | 4 | H |

**5.4 Full Approach.** The full technical risk assessment approach is a semi-quantitative assessment of the risk to sufficiently developing each KT within predetermined time constraints. The assessment is based on the probability of the technology being sufficiently matured, integrated, and manufacturable within the required timeframe (e.g., MS B and C). The probabilities are based on SME input and forecasts, or historical data. AMSAA conducts a risk workshop to review SME input to support the full approach. The assessment approach includes the following:

- *Step 1:* Identify technologies for each alternative based on the Systems Book for the study.
- *Step 2*: Gather relevant technology and alternative information.
- *Step 3*: Secure SME support for readiness level assessment. APPENDIX D – contains sample readiness assessment guidance for RDECs to issue to SMEs.
- *Step 4*: SMEs assess TRL, IRL, and MRL for each identified technology in the Program Systems Book.
- *Step 5*: Identify technical risks, risk ratings, and potential mitigation strategies for each technology.
- Step 6: SMEs identify KTs to include in the risk assessment.
- *Step 7*: Conduct risk workshop.
- *Step 8*: Determine technical risk rating for each KT using the risk reporting matrix from the Risk Management Guide for DOD Acquisition.[14]
- *Step 9*: Perform sensitivity analysis on the risk rating.

Each step of the approach is further explained in subsequent sub-sections.

[14] Risk Management Guide for DOD Acquisition, Department of Defense, August 2006.

#### 5.4.1 Step 1: Identify technologies for each alternative.

The primary source used to describe technologies for each of the alternative systems is the study Systems Book. AMSAA is usually tasked with maintaining the approved Systems Book for study consistency. The Systems Book is the authoritative source for describing each alternative assessed in the particular study. It provides basic descriptions of each system, to include technologies. Technologies identified in the Systems Book for each alternative should be the technologies assessed by the RDEC SMEs. The final list of technologies to be assessed for each alternative should be agreed to by the study team, to include the appropriate PM.

#### 5.4.2 Step 2: Gather relevant technology and alternative information.

Gathering all available information for each technology is essential for the SMEs to provide a relevant and valuable assessment. In some cases, the PM may assist in providing technology information. Having the Capability Development Document (CDD) requirements available for the SMEs during their evaluation is important to the assessment process, as it allows the SMEs to evaluate the ability of the technology to meet the program's requirements. For assessments on pre-MS A systems, the Initial Capabilities Document (ICD) or draft CDD will suffice.

#### 5.4.3 Step 3: Secure SME support for readiness level assessment.

Identify SMEs for each identified technology. Technology SMEs will usually be found within the Research, Development, and Engineering Command (RDECOM) (e.g. RDECs, ARL) or AMSAA. It is important to request SME participation in the assessment as early as possible, and determine whether they will require funding. A kick-off meeting to provide guidance on the technical risk assessment, including required deliverables and the timeline for the activity, will ensure SME understanding of their assessments.

#### 5.4.4 Step 4: SMEs assess TRL, IRL, and MRL for each technology.

SMEs should use all available information for the technology under evaluation to make the best possible assessment. To evaluate the probability of a technology meeting the required TRL within the required timeframe, the current TRL of each identified technology must be assessed. For pre-MS B AoAs, the current TRLs should be obtained from the Deputy Assistant Secretary of the Army for Research & Technology (DASA R&T) TRA, if timing of the TRA supports the technical risk assessment. Close coordination with DASA R&T and the PM must occur to ensure the TRLs used in the technical risk assessment are the same as in the formal TRA. If possible, the same TRA SMEs should provide IRL and MRL assessments for the technical risk assessment.

For pre-MS A AoAs completed prior to any formal TRA, and for pre-MS B AoAs where the timing of the TRA does not support the technical risk assessment, a TMA or early evaluation of technology maturity must be completed to support the technical risk assessment. The TMA helps evaluate technology alternatives and risks and, thereby, helps the PM refine the plans for achieving mature technologies at MS B. The TMA must be coordinated with the PM and RDEC

to ensure appropriate SMEs are assigned to the assessment. The preferred process is for the applicable RDEC (e.g., TARDEC for ground systems, AMRDEC for aviation systems, etc.) to lead the TMA following the general guidelines of the DOD TRA Guidance (April 2011). SMEs must assess TRL, IRL, and MRL for each technology. These readiness level assessments will be reviewed at the risk workshop so as to achieve group consensus on assessed levels.

Guidance in the form of definitions, descriptions, and questions to consider is provided to the SMEs performing the TRL, MRL, and IRL assessments for a given technology. The TRL criteria used are shown in APPENDIX A –and are taken from the DOD TRA Guidance (April 2011). The IRL criteria used are shown in APPENDIX B –. Since no DOD standard currently exists for definitions of integration readiness, the IRL definitions used for the technical risk assessment are based on the Stevens Institute of Technology IRL criteria, with modifications made by TARDEC. The MRL criteria used are shown in APPENDIX C –and are taken from the DOD MRL Deskbook, Version 2.01, July 2011.[15] SMEs conducting the assessment must provide a rationale for all assigned readiness level ratings. TRL/MRL/IRL mapping guidelines for the program lifecycle are shown in Figure 4.[16] This mapping shows the relationships between TRL, MRL, and IRL for each phase of the lifecycle. The mapping of IRLs to the lifecycle was developed by TARDEC and is still considered Draft, pending further socialization of IRLs. Normal technology development requires attainment of a TRL before the equivalent MRL and IRL can be attained.

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[15] Department of Defense Technology Readiness Assessment (TRA) Guidance, Office of the Assistant Secretary of Defense for Research and Engineering (ASD (R&E)), April 2011.
[16] Manufacturing Readiness Level (MRL) Deskbook – Version 2.2, OSD Manufacturing Technology Program in conjunction with The Joint Service/ Industry MRL Working Group, July 2012

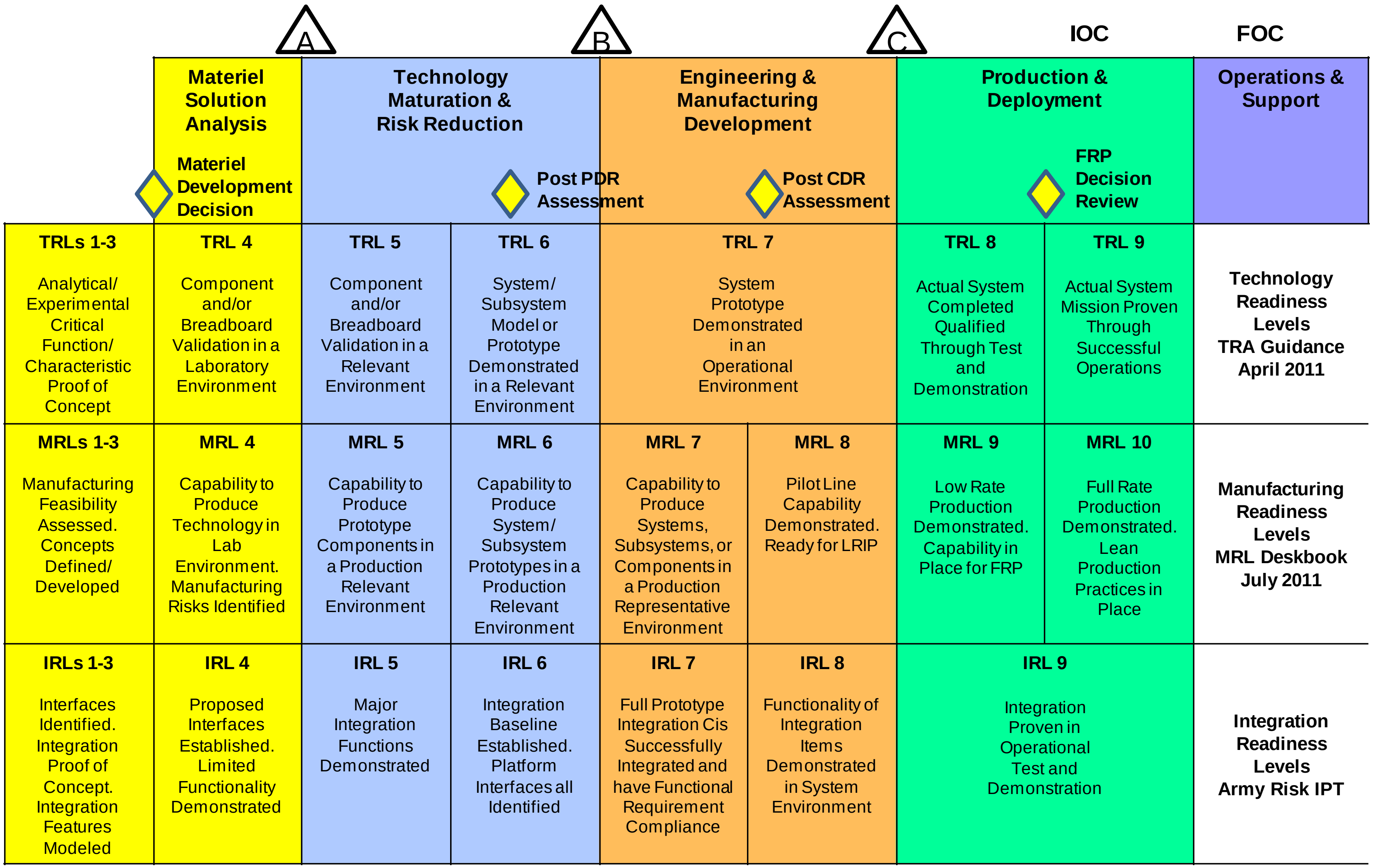



**Figure 4. TRL/MRL/IRL Mapping**

### 5.4.5 Step 5: Identify technical risks, risk ratings, and mitigations.

In addition to the assignment of TRL, MRL, and IRL levels, the SMEs are asked to identify any known or potential technical risks associated with the assessed technology. These risks should serve as input to and influence the TRL, MRL, and IRL assessments. The risk should be stated in one clear and concise sentence, creating an "IF … THEN … MAY" statement. For example, if the current engine design is used instead of a redesigned accessory drive, then there may be engine overheating and vehicle mission failures. The details of the risk should include who, what, where, when, why, and how much risk. For each identified technical risk, the SME should independently rate the likelihood and consequence of each risk using the standard DOD Acquisition risk reporting matrix (Figure 2) and the criteria as stated in the Risk Management Guide for DOD Acquisition (August 2006) or other program-designated criteria. For example, TARDEC together with PEO GCS have created definitions for use in assessments of ground systems in a Risk Recon Risk Management Tip Sheet as shown in Figure 5 below.

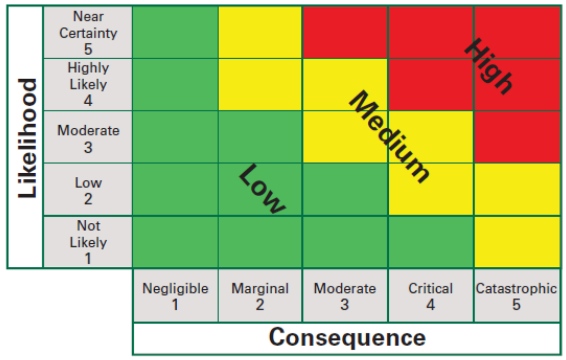
In addition, SMEs should identify any potential mitigation actions for the risk, and capture this as part of their risk assessment. Risk mitigation planning identifies, evaluates, and selects options to set risk at acceptable levels given program constraints and objectives. It includes the specifics of what should be done, when it should be accomplished, who is responsible, and the funding and schedule tasks required to implement the risk mitigation plan.[17]

Once the SMEs have completed the readiness level assessments and identification of technical risks as part of the TMA, the overall lead (e.g. TARDEC Systems Engineering Group) should conduct a workshop to review and finalize the SME assessments prior to the AMSAA-led risk workshop.

[17] Risk Management Guide for DOD Acquisition, Sixth Edition, Version 1.0, August 2006 and Defense Acquisition Guidebook, August 5, 2010.

Risk Recon Risk Management Tip Sheet

**Risk Recon Website:**
https://peoportalap.tacom.army.mil/riskmgmt
**POCs:** Lisa.Graf@us.army.mil
George Wiklund@us.army.mil




| Risk Information Sheet | |
|---|---|
| **Description of Risk Condition** | State the risk in one clear and concise sentence, creating an "IF..THEN...MAY" statement or a brief description. |
| **Context** | Details of the risk - the Who, What, Where, When, Why, How and How Much of the risk. |
| **Consequence** | What are the impacts to the program in terms of Cost, Schedule, Performance or Other if this risk becomes an issue. |
| **Mitigation Plan** | This is the detailed mitigation plan - what will be done to mitigate the risk. List steps with due dates, owners and impact to the risk. |
| **CloseOut Rationale** | List the agreed upon details for closing this risk - who agreed to close it at what meeting, date and for what reasons. |

| Likelihood - Probability Levels and Indicators |
|---|
| **5 (Near Certainty) - Assume & anticipate occurrence (>90%)** Approach and processes cannot mitigate risk; Immature technology; System very complex |
| **4 (Highly Likely) - Very high chance of occurrence (>65% to 90%)** Approach and processes not well documented; Technology available but not validated |
| **3 (Moderate) - Significant chance of occurrence (> 40% to 65%)** Approach and processes are partially documented; Un-validated technology has been shown to be feasible by analogy, test, or analysis |
| **2 (Low Likelihood) - Occurrence possible but less than likely (10% to 40%)** Current approach and processes understood & documented; most technology has been validated |
| **1 (Not Likely) - Occurrence is possible but very unlikely (<10%)** Approach and processes are well understood and documented |

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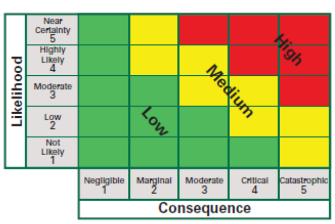
Risk Recon Risk Management Tip Sheet




*"Knowing our risks provides opportunities to manage and improve our chances of success."*
—Roger Vanscoy

**Consequence Table**

| Rating/Description | Performance | Cost | Schedule |
|---|---|---|---|
| **5 (Catastrophic)** - Jeopardizes an exit criterion of current acquisition phase | Unacceptable; No viable alternatives exist | Program budget impacted by 10% or more; Program success jeopardized | Key events or milestones delayed by more than one month |
| **4 (Critical)** Potentially fails Key Performance Parameter (KPP) | Unacceptable; Significant changes required | Program budget impacted by 5%-10%, Significant portion of program management reserves must be used to implement workarounds | Critical path activities 2 weeks late; Workarounds would not meet milestones, Program success in doubt |
| **3 (Moderate)** Shorts a critical mission need but expect no breech of KPP threshold requirements | Below goal; Moderate changes required; Alternatives would provide acceptable system performance; Limited impact on program success | Budget impacted by 1%-5%; Limited impact on program success; Does not require significant use of program cost and or schedule reserves | Non-critical path activities one month late; Workarounds would avoid impact on critical path; Limited impact on program success |
| **2 (Marginal)** Requires the commitment of a minor portion of the program cost, schedule or performance reserve | Below goal but within acceptable limits; No changes required; Acceptable alternatives exist; Minor impact on program success | Budget impacted by 1% or less; Minor impact on program success; Minor program management reserves (schedule, cost) used for workarounds | Non-critical path activities late; Workarounds would avoid impact on key and non-key milestones; Minor impact on program success; Development schedule goals exceeded by 1%-5% |
| **1 (Negligible)** Remedy will require minor cost, schedule and/or performance trades | Requires minor performance trades within the threshold - objective range; No impact on program success | Budget not dependent on the issue; No impact on program success, Cost increase can be managed within program plan | Schedule not dependent on issue; No impact on program success; Schedule adjustments managed within program plan |

| Terms | Definitions |
|---|---|
| *Risk* | A measure of future uncertainties in achieving program performance goals and objectives within defined cost, schedule and performance constraints. Risk addresses the *potential* variation in the planned approach and suspected outcome. |
| *Issue* | An event that has already occurred or has 100% likelihood of occurring. |
| *Likelihood* | Probability that the risk will occur (based on ratings 1-5). |
| *Consequence* | Effect or impact on the program if risk becomes an issue (based on ratings 1-5). |

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**Figure 5. TARDEC Risk Recon Tip Sheet**

### 5.4.6 Step 6: SMEs identify key technologies.

Having confirmed the guidance and processes used in the assessment, SMEs must identify the KTs from the list of technologies under consideration. KTs should be determined similarly to guidance in DOD TRA Guidance (April 2011) for determining whether or not a technology is critical. The technologies included in the assessment should be KTs for the alternative, although other technologies of interest can also be included in the assessment. The criteria used to determine KTs are as follows:

1. Does the technology pose major technological risk during development?
2. Does the system depend on this technology to meet Key Performance Parameters (KPP), Key System Attributes (KSA), or designed performance?
3. Is the technology or its application new or novel or is the technology modified beyond initial design intent?

If the answer to question 1 is ‘Yes’, then the technology is key. If the answer to both questions 2 AND 3 are ‘Yes’, then the technology is also key. A rationale explaining why the technology has been identified as a KT is required and must be provided by each technology SME.

### 5.4.7 Step 7: Conduct risk workshop.

AMSAA will conduct a risk workshop to facilitate the gathering of data to support the technical, schedule, and cost risk assessments. Broad participation from study stakeholders is required for workshop success. Participation from the following organizations is desired: AMSAA, ODASA-CE, TRADOC Centers of Excellence, RDECOM (RDECs and ARL), PEO/PM, HQDA/OSD Action Officers, TRAC, ARCIC, and the Army Test and Evaluation Command (ATEC).

Workshop efficiency requires a formal structure to properly gather required information. The recommended workshop structure is shown below.

- Technical Risk. For each KT:
  - Review TRL, IRL, and MRL for each KT. Group must come to agreement on accurate readiness levels for each technology.
  - Assess expected transition times for each KT to reach the required TRL, IRL, and MRL (see examples below). Group must come to consensus on expected transition times.
    - TRL 6, IRL 6, and MRL 6 at MS B, and
    - TRL 7, IRL 8, and MRL 8 at MS C.
  - Use Monte Carlo simulation to model the expected likelihood (probability) from the assessed transition times. Use likelihood level criteria shown in Table 2 to map the likelihood (probability) to a likelihood level. Section 5.4.8 provides additional details on how to determine the likelihood level.
  - Assess consequence if technology is not sufficiently developed (i.e., technology matured, integration characterized, and manufacturing processes

matured) by the required timeframe. Use consequence level criteria shown in Table 3 based on probable PM mitigation to address the issue: accept decreased performance (holding schedule and cost fixed), increase program schedule (holding performance and cost fixed), or increase program cost (holding performance and schedule fixed). Section 5.4.8 provides additional details on how to determine the consequence level.

  - Consequence to technical performance should be addressed by considering alternative technologies that could be sufficiently developed in required timeframe and cost, and their impact to key performance attributes or parameters.
  - Consequence to schedule should be addressed by comparing planned development time to the estimated maximum total transition time for the technology. Technology maximum total transition time estimate should be determined by:

$$\boldsymbol{TRL}(\boldsymbol{max}) + \boldsymbol{max}\,\{\boldsymbol{IRL}(\boldsymbol{max}), \boldsymbol{MRL}(\boldsymbol{max})\} \tag{1}$$

Where, TRL (max) = maximum TRL transition time estimate
IRL (max) = maximum IRL transition time estimate
MRL (max) = maximum MRL transition time estimate

  - Consequence to cost should be addressed by considering both cost impacts of using the alternative technology and cost of schedule delays if maximum transition times are experienced.

- Identify other technical risk factors that impact cost and schedule elements.

- Schedule Risk. For each alternative:
  - Identify/confirm analogous historical programs.
  - Identify schedule risk drivers.
  - Identify events that impact schedule risk.
  - Identify schedule risk factors that impact technical and cost elements.

- Cost Risk. For each alternative:
  - Identify high risk areas for development, production, and operations and support (O&S).
  - Identify cost risk factors for use as potential trade space mitigation strategies to reduce technical and/or schedule risk.
  - Identify data accuracy impact on cost risk.

#### 5.4.8 Step 8: Determine technical risk rating for each key technology.

This section provides the detailed methodology to be used in determining the technical risk rating for each KT. The technical risk rating measures the risk that the technology is not sufficiently developed within the given timeframe. The rating is based on the probability of the technology being sufficiently matured, integrated, and manufacturable within the required

timeframe, as well as the consequence to technical performance, schedule, and cost if not sufficiently developed. The rating is assessed using the standard DOD Acquisition risk reporting matrix as shown in Figure 2. The technical risk rating is defined by likelihood and consequence of event occurrence.

Likelihood measures the probability that the technology **will not** be sufficiently matured, integrated, and manufacturable within the given timeframe (e.g., MS B and C). Likelihood calculations are based on three elements:

- Level of developmental effort remaining to reach the required TRL by the planned milestone date (e.g., TRL 6 at MS B and TRL 7 at MS C). This is measured by eliciting expected transition times for the technology to reach the required readiness levels (given the current TRL) from SMEs. Elicited transition time estimates contain minimum, most-likely and maximum time periods.
- Additional level of integration effort remaining to reach the required IRL by the planned milestone date (e.g., IRL 6 at MS B and IRL 8 at MS C), given that TRL 6 (for MS B) or TRL 7 (for MS C) is achieved. This is measured by eliciting expected transition times (beyond that estimated to get to TRL 6 and TRL 7) for the technology to reach IRL 6 and IRL 8 (given the current IRL) from SMEs. Elicited transition time estimates will contain minimum, most-likely and maximum time periods.
- Additional level of manufacturing effort remaining to reach the required MRL by the planned milestone date (MRL 6 at MS B and MRL 8 at MS C), given that TRL 6 (for MS B) and TRL 7 (for MS C) is achieved. This is measured by eliciting expected transition times (beyond that estimated to get to TRL 6 and TRL 7) for the technology to reach MRL 6 and MRL 8 (given the current MRL) from SMEs. Elicited transition time estimates will contain minimum, most-likely and maximum time periods.

Monte Carlo simulation using @RISK software is used to determine the likelihood from the three elicited transition time estimates (TRL, IRL, and MRL). A simple three-event model of the elicited transition time estimates is built in @RISK. The transition time estimates are modeled as triangular distributions (minimum, most-likely, and maximum times). Random deviates are drawn from each of the three triangular distributions ($trl_i$, $irl_i$, and $mrl_i$). Since IRL and MRL are dependent on TRL, but not each other, the total time required to develop the technology is determined by:

$$\boldsymbol{Total\ time\ (T_i) = \mathbf{trl_i} + \mathbf{max}\ \{irl_i, mrl_i\}} \qquad (2)$$

This process is repeated 10,000 times in the Monte Carlo simulation to create a distribution for the total time required to develop the technology (T). The time remaining until either MS B or MS C is plotted on the distribution of T to calculate the likelihood probability that the technology will not be sufficiently developed by the applicable milestone. Likelihood level criteria are used to map the likelihood probability to a likelihood level in the DOD Acquisition risk reporting matrix (Figure 2).

Consequence is assessed to technical performance, schedule, and cost if the technology is not sufficiently developed within the required timeframe. Use consequence level criteria shown in Table 3. Consequence to technical performance should be addressed by considering

alternative technologies that could be used and their impact to technical performance. Consequence to schedule should be addressed through the estimated maximum transition times for the technology. Consequence to cost should be addressed by considering both cost impacts of using the alternative technology and cost of schedule delays if maximum transition times are experienced.

Likelihood level and consequence level are plotted on the DOD Acquisition risk reporting matrix in Figure 2 to determine the risk rating for the technology (low, moderate, or high).

#### 5.4.9 Step 9: Perform sensitivity analysis on the risk rating.

Sensitivity analysis can be performed after the risk rating for each KT is determined. The acquisition milestone dates can be modified to determine how many additional months need to be added to the schedule to reduce the risk rating. The results of the sensitivity analysis can aid in identifying potential trade options.

**5.5 Validation.** Validation of this technical risk assessment methodology cannot occur until after several years of application to multiple systems from which comparisons can be made against actual program progress.

**5.6 Data Development.** To date, there are no data sources from which to draw current readiness levels or historical readiness level progressions over time for use in the technical risk assessment. The data development approach for each assessment is shown below:

- Current technology readiness levels: The technical risk assessment should be coordinated with the formal TRA, if timing of the study permits, to ensure consistent readiness level ratings. A TRA is a systematic, metrics-based process that assesses the maturity of, and the risk associated with, KTs used in Major Defense Acquisition Programs (MDAPs), to include Acquisition Category (ACAT) ID and IC programs. The PM conducts the TRA with the assistance of an independent team of SMEs that make up the Independent Review Team (IRT). A TRA is required by DODI 5000.02 for MDAPs at MS B (or at a subsequent MS if there is no MS B). It is also conducted whenever otherwise required by the Milestone Decision Authority (MDA).[18] If timing of the study does not permit coordination with the formal TRA, then an informal TMA must be conducted by RDEC technology SMEs to support the technical risk assessment.

- Estimated technology transition times to TRL 6, IRL 6, MRL 6 and TRL 7, IRL 8, MRL 8. Currently these estimated transition times must be elicited from technology SMEs. Technology maturity data may be obtained from PEOs/PMs and from industry through Requests for Information (RFIs) or Requests for Proposal (RFPs). Required data must track technology maturation over time by updating readiness levels to reflect current state of technical development.

[18] Department of Defense Technology Readiness Assessment (TRA) Guidance, Office of the Assistant Secretary of Defense for Research and Engineering (ASD (R&E)), April 2011.

**5.7 Data Sources.** Currently, SME judgment must be used to assess the required technology transition times to TRL 6, IRL 6, MRL 6 and/or TRL 7, IRL 8, MRL 8.

In addition, AMSAA is populating a Historical Risk Database with readiness level data from these assessments. Data can be used to ensure consistency in ratings (e.g., at times, more than one concurrent AoA includes the same KTs), as well as assisting in future methodology validation.

**5.8 Responsibilities.** The following organizations are responsible for the technical risk assessment.

- AMSAA: lead the technical risk assessment; conduct risk workshop.
- RDEC:
    - Systems Engineering Group:
        - Lead the TRA/TMA.
        - Provide guidance to the technology SMEs to aid in identifying KTs, assessing current TRLs, IRLs, and MRLs, and identifying/assessing technical risks.
        - Contribute to assessments on technology transition times.
    - Technology SMEs:
        - Assess current TRLs, IRLs, and MRLs.
        - Identify KTs,
        - Identify/ assess technical risks.
        - Contribute to assessments on technology transition times.
- TRADOC Centers of Excellence: represent users and contribute to assessments on technical performance consequences.
- PEO/PM:
    - Contribute to assessments on technology transition times and consequence determination for technical performance, schedule, and cost.
    - Assist in providing technology information.
    - Provide PM schedule for each alternative.

**5.9 Example.** Described below is an example of the steps required to conduct a technical risk assessment following the full approach. All data is notional. This assessment is notionally part of a pre-MS A AoA for an Air Defense System. Study guidance dictates the technical risk assessment measure the risk to each KT being sufficiently developed by the planned MS C, which is 65 months from MS A.

**5.9.1 Step 1: Identify technologies for each alternative.**

Table 5 shows the list of technologies from the Systems Book for a notional Air Defense System 1 alternative. This list must be agreed to by the study team. These technologies will be assessed by technology SMEs in the Technology Maturity Assessment.

**Table 5. Technologies for Air Defense System 1 Alternative**

| Alternative | Component | Technology |
|---|---|---|
| **Air Defense System 1** | Fire Control Radar | Transmit Antenna |
| | | Receive Antenna |
| | | Processor Electronics |
| | Weapon | Barrel |
| | | Receiver |
| | | Feeder |

The Systems Book does not provide much detailed information on the individual technologies so SMEs must gather relevant technology information.

### 5.9.2 Step 2: Gather relevant technology and alternative information.

The Systems Book provides basic descriptions of each alternative system and a list of included technologies. More detailed information on the included technologies must be gathered to provide accurate assessments. A Work Breakdown Structure (WBS) for the alternative system could provide some additional level of detail. Other technology information can be gathered from the following sources and should be used by the SMEs to assess readiness levels and determine KTs:

- Purchase description
- Test data
- Requirements data
- Prototyping information
- Modeling and simulation analyses
- Risk data
- Issues data
- Trade studies
- Engineering presentations
- System interface analyses
- Manufacturing data
- Contractor-provided data.

### 5.9.3 Step 3: Secure SME support for readiness level assessment.

Since this is a gun-based Air Defense System, ARDEC should be considered to lead the Technology Maturity Assessment. Table 6 shows the list of possible organizations from which to find potential SME support for assessing maturity. ARDEC should coordinate directly with the organizations to identify appropriate SMEs for each technology.

**Table 6. Organizations for Potential SME Support**

| Alternative | Component | Technology | SME Organizations |
|---|---|---|---|
| **Air Defense System 1** | Fire Control Radar | Transmit Antenna | CERDEC, AMRDEC, SMDC, ARL |
| | | Receive Antenna | |
| | | Processor Electronics | |
| | Weapon | Barrel | ARDEC, SMDC, ARL |
| | | Receiver | |
| | | Feeder | |

Once SMEs are identified for each technology, guidance can be issued by ARDEC on the conduct of the Technology Maturity Assessment.

### 5.9.4 Step 4: SMEs assess TRL, IRL, and MRL for each technology.

APPENDIX D –contains sample technical risk assessment guidance that should be issued to the technology SMEs before they begin their assessment. Table 7 shows notional results for the current readiness level assessments for Air Defense System 1.

**Table 7. Readiness Level Assessments**

| Alternative | Component | Technology | TRL | IRL | MRL |
|---|---|---|---|---|---|
| **Air Defense System 1** | Fire Control Radar | Transmit Antenna | 6 | 5 | 5 |
| | | Receive Antenna | 6 | 5 | 5 |
| | | Processor Electronics | 5 | 4 | 4 |
| | Weapon | Barrel | 5 | 5 | 5 |
| | | Receiver | 6 | 5 | 5 |
| | | Feeder | 4 | 3 | 3 |

### 5.9.5 Step 5: Identify technical risks, risk ratings, and mitigations.

Technology SMEs should also provide rationale for all assigned readiness levels. In addition, the SMEs should identify specific technical risks for each technology along with an associated risk level and possible risk mitigations. Table 8 shows notional technical risks, assessed risk levels, and mitigations for the Air Defense System 1 alternative.

**Table 8. Identified Technical Risks**

| Alternative | Component | Technology | Technical Risks | Assessed Risk Level | Mitigations |
|---|---|---|---|---|---|
| **Air Defense System 1** | Fire Control Radar | Transmit Antenna | If the transmit antenna cannot command detonate the warheads then the system may not meet all lethality requirements. | Moderate | Protoptype radar to be demonstrated in 24 months. |
| | | Receive Antenna | If the receive antenna cannot track and communicate simultaneously then the system may not meet all lethality requirements. | Moderate | Protoptype radar to be demonstrated in 24 months. |
| | | Processor Electronics | If the new processor design doesn't meet speed specifications then system may not meet engagement requirements. | Low | Protoptype radar to be demonstrated in 24 months. |
| | Weapon | Barrel | If barrels cannot be optimized for C-RAM engagements then system may not meet lethality requirements . | Low | Use currently available barrels with slightly different geometries. |
| | | Receiver | If receiver isn't able to support the required shots per minute then the system may not meet required operational performance. | Low | Fund to demonstrate at required performance. |
| | | Feeder | If receiver isn't able to support the required shots per minute then the system may not meet required operational performance. | Low | Fund to demonstrate at required performance. |

These identified technical risks can be used to help determine the KTs for the alternative.

### 5.9.6 Step 6: SMEs identify key technologies.

The criteria outlined in section 5.4.6 above should be used to identify KTs and provide supporting rationale. Table 9 shows notional key technology recommendations for Air Defense System 1: transmit antenna, receive antenna, and feeder. Study team approval of these key technologies is important. Upon approval, these KTs will be the only technologies included in the technical risk assessment, unless the study team feels other technologies should be included.

**Table 9. Identified Key Technologies**

| Alternative | Component | Technology | Key (Y/N) |
|---|---|---|---|
| **Air Defense System 1** | Fire Control Radar | Transmit Antenna | Y |
| | | Receive Antenna | Y |
| | | Processor Electronics | N |
| | Weapon | Barrel | N |
| | | Receiver | N |
| | | Feeder | Y |

ARDEC should conduct a SME workshop prior to the AMSAA-led risk workshop to review all assessments and ensure accuracy. Table 10 shows the notional results of the Technology Maturity Assessment.

**Table 10. Technology Maturity Assessment Results**

| Alternative | Component | Key Technology | TRL | IRL | MRL | Technical Risks | Assessed Risk Level | Mitigations |
|---|---|---|---|---|---|---|---|---|
| Air Defense System 1 | Fire Control Radar | Transmit Antenna | 6 | 5 | 5 | If the transmit antenna cannot command detonate the warheads then the system may not meet all lethality requirements. | Moderate | Protoptype radar to be demonstrated in 24 months. |
| | | Receive Antenna | 6 | 5 | 5 | If the receive antenna cannot track and communicate simultaneously then the system may not meet all lethality requirements. | Moderate | Protoptype radar to be demonstrated in 24 months. |
| | Weapon | Feeder | 4 | 3 | 3 | If receiver isn't able to support the required shots per minute then the system may not meet required operational performance. | Low | Fund to demonstrate at required performance. |

### 5.9.7 Step 7: Conduct risk workshop.

AMSAA will conduct a risk workshop after the TMA is finalized. During the workshop, SMEs in attendance will conduct an independent review of the readiness levels, so as to ensure their validity. Table 11 shows group consensus results from the AMSAA-led risk workshop. It shows estimated transition times to TRL 7, IRL 8, and MRL 8 for each of the KTs. (In addition, TRL 6, IRL 6, MRL 6 transition tames may be elicited, providing additional information to the decision maker.)

**Table 11. Transition Time Estimates**

| Alternative | Component | Key Technology | Time (months) to reach TRL 7 | | | Additional time (months) beyond TRL 7 to reach IRL 8 | | | Additional time (months) beyond TRL 7 to reach MRL 8 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Min | Most Likely | Max | Min | Most Likely | Max | Min | Most Likely | Max |
| Air Defense System 1 | Fire Control Radar | Transmit Antenna | 36 | 48 | 68 | 6 | 18 | 33 | 0 | 6 | 10 |
| | | Receive Antenna | 28 | 36 | 58 | 6 | 12 | 37 | 0 | 6 | 10 |
| | Weapon | Feeder | 36 | 54 | 75 | 0 | 6 | 22 | 0 | 0 | 9 |

Consequences if the KTs are not available in the required timeframe were also assessed at the risk workshop. Performance of the KTs was determined critical to Air Defense System 1 and could not be traded. Appropriate PM mitigation for all three KTs would be to increase the schedule to allow technology development. Consequence level determination would be based on results of *TRL(max) + max{IRL(max),MRL(max)}* compared to the planned MS C date in 65 months. Table 12 shows the resulting consequence levels for each KT. Consequence level definitions from Table 3 were tailored during the risk workshop.

**Table 12. Consequence Level Assessments**

| Key Technology | TRL(max) | IRL(max) | MRL(max) | Total Maximum Transition Time (months) | MS C Planned Date Difference (65 months) | Consequence Level |
|---|---|---|---|---|---|---|
| Transmit Antenna | 60 | 24 | 8 | 84 | 19 | 4 |
| Receive Antenna | 50 | 24 | 8 | 74 | 9 | 2 |
| Feeder | 62 | 12 | 6 | 74 | 9 | 2 |

The technical risk rating for each KT was determined with this elicited information.

### 5.9.8 Step 8: Determine technical risk rating for each key technology.

The technical risk rating for each KT is determined as described in section 5.4.8. Likelihood measures the probability that the technology **will not** be sufficiently matured, integrated, and manufacturable by MS C, which is planned for 65 months from MS A. @RISK software was used to run Monte Carlo simulations on the transition time estimates in Table 11 as described in section 5.4.8. Table 13 shows the results of the Monte Carlo simulations for the likelihood.

**Table 13. Monte Carlo Results for Likelihood**

| Alternative | Component | Key Technology | Likelihood (L) |
|---|---|---|---|
| **Air Defense System 1** | Fire Control Radar | Transmit Antenna | 0.69 |
| | | Receive Antenna | 0.25 |
| | Weapon | Feeder | 0.47 |

Likelihood level definitions from Table 2 were used to map results from Table 13 to a likelihood level that can be plotted in the risk reporting matrix. Table 14 shows the resulting likelihood levels and risk ratings for each of the KTs.

**Table 14. Risk Rating Results**

| Alternative | Component | Key Technology | Likelihood (L) | Likelihood Level | Consequence Level | Risk Rating |
|---|---|---|---|---|---|---|
| **Air Defense System 1** | Fire Control Radar | Transmit Antenna | 0.69 | 4 | 4 | High |
| | | Receive Antenna | 0.25 | 2 | 2 | Low |
| | Weapon | Feeder | 0.47 | 3 | 2 | Low |

#### 5.9.9 Step 9: Perform sensitivity analysis on the risk rating.

Risk rating sensitivity analysis is done iteratively in @RISK by increasing the milestone date until the likelihood probability results in a lower risk rating. Table 15 shows the results of the sensitivity analysis performed in @RISK. The table shows the additional number of months that need to be added to the schedule to reduce the risk rating for the transmit antenna from high to moderate and low.

**Table 15. Sensitivity Analysis Results**

| Alternative | Component | Key Technology | Number of Months Added to Schedule | New Likelihood | New Likelihood Level | Consequence Level | New Risk Rating |
|---|---|---|---|---|---|---|---|
| **Air Defense System 1** | Fire Control Radar | Transmit Antenna | 2 | 0.60 | 3 | 4 | Moderate |
| **Air Defense System 1** | Fire Control Radar | Transmit Antenna | 12 | 0.20 | 1 | 4 | Low |

## 6. SCHEDULE RISK ASSESSMENT

**6.1 Background.** One of the top priorities of the US Army is to make decisions regarding acquisition programs that will best serve the Warfighter. WSARA requires full consideration of possible trade-offs among cost, schedule, and performance objectives to support the AoA. Providing a useful and informative schedule risk assessment for a set of alternatives is a key input to the decision making process.

Senior Army and OSD leaders have requested increased quantitative emphasis of schedule risk modeling. The use of historical analogous data to perform the modeling was also desired. The schedule risk assessment described below follows this guidance by incorporating quantitative methods and historical data.

**6.2 Purpose.** The schedule risk assessment measures the schedule risks associated with an Army acquisition system in order to provide the following information to decision makers and the PM:

- Information and data on historical analogous programs.
- Probability of meeting schedule deadline(s).
- Risk rating based on the probability of meeting schedule deadlines and/or historical data.
- Identification of schedule risk drivers.
- Potential risk mitigation strategies.

**6.3 Analogous Programs.** Selecting historical analogous programs are an integral part of the schedule risk assessment methodology. The programs are chosen based on several key factors, such as:

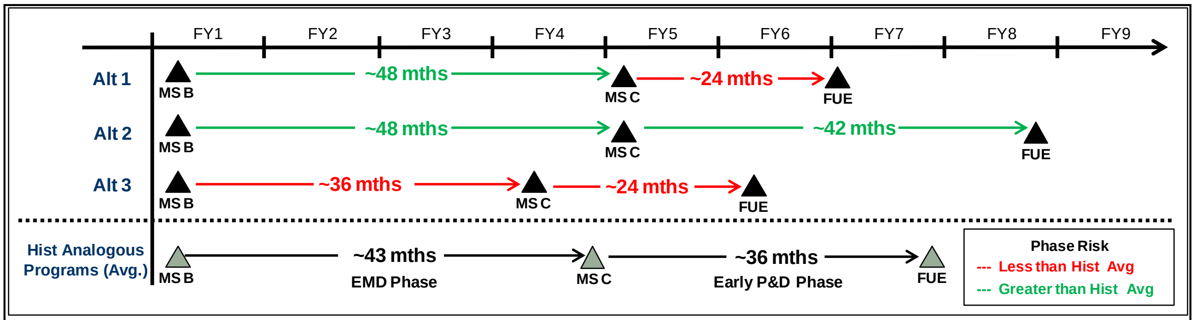
- Program type (surface, air, sea, missile, etc.)
- Acquisition Strategy
    - Non-developmental Item, Commercial Off the Shelf, Government Off the Shelf, New Start
    - Acquisition Category (I, II, III)
    - Domestic, Foreign
    - Contract Type
    - Stability of Funding
- System Capabilities
- Key Technologies

The factors for selecting analogous programs are still being developed and refined. No mathematical approach or calculations are currently used to determine the analogous programs based on these factors. The existing process is for AMSAA to develop an initial list of analogous programs, by considering the above key factors, and then for consensus to be reached during the risk workshop.

**6.4 Quick-Turn Approach.** The quick-turn schedule risk assessment approach is a qualitative assessment that compares each AoA alternative’s proposed schedule to historical analogous programs by acquisition lifecycle phase. A qualitative risk rating is assigned to each

alternative based on comparison to historical averages, known schedule delays for historical analogous programs, SME input, and technical risk assessment results. This type of schedule risk assessment is primarily driven by historical data limitations and time constraints based on completion date of the study. An example of this approach is shown in Section 6.4.1.

**6.4.1 Quick-Turn Approach Example.** A notional example of the quick-turn schedule risk assessment approach is provided in Figure 6. Each AoA alternative's proposed schedule is compared to historical analogous programs by acquisition lifecycle phase. An overall schedule risk rating is assigned to each alternative based on the worst rating received for an individual phase. In addition, information regarding delays encountered by the historical programs is beneficial to provide to the decision maker.




Schedules of Historical Analogous Programs

| Historical Programs | EMD Phase (mths) | Early P&D Phase (mths) |
|---|---|---|
| Program 1 | 39 | 27 |
| Program 2 | 42 | 46 |
| Program 3 | 47 | 36 |
| Historical Average | 43 | 36 |

*Overall Schedule Risk Ratings:*

| |
|---|
| Alternative 1 |
| Alternative 2 |
| Alternative 3 |

**Figure 6. Notional Quick-Turn Schedule Risk Assessment Example**

**6.5 Full Approach.** AMSAA developed a Schedule Risk Data Decision Methodology (SRDDM) that begins by determining if sufficient historical data exists to use quantitative techniques in conducting the schedule risk assessment. SRDDM uses Monte Carlo simulations, bootstrapping, and/or mathematical models to build a confidence interval (CI) for the probability of meeting the PM's schedule. If this CI width is within tolerance (refer to APPENDIX E –for more information on error tolerance), then sufficient analogous programs exist to conduct the final steps of the SRDDM schedule risk assessment. Otherwise, a quick-turn schedule risk assessment approach must be used. The flowchart in Figure 7 below presents a high-level overview of SRDDM:

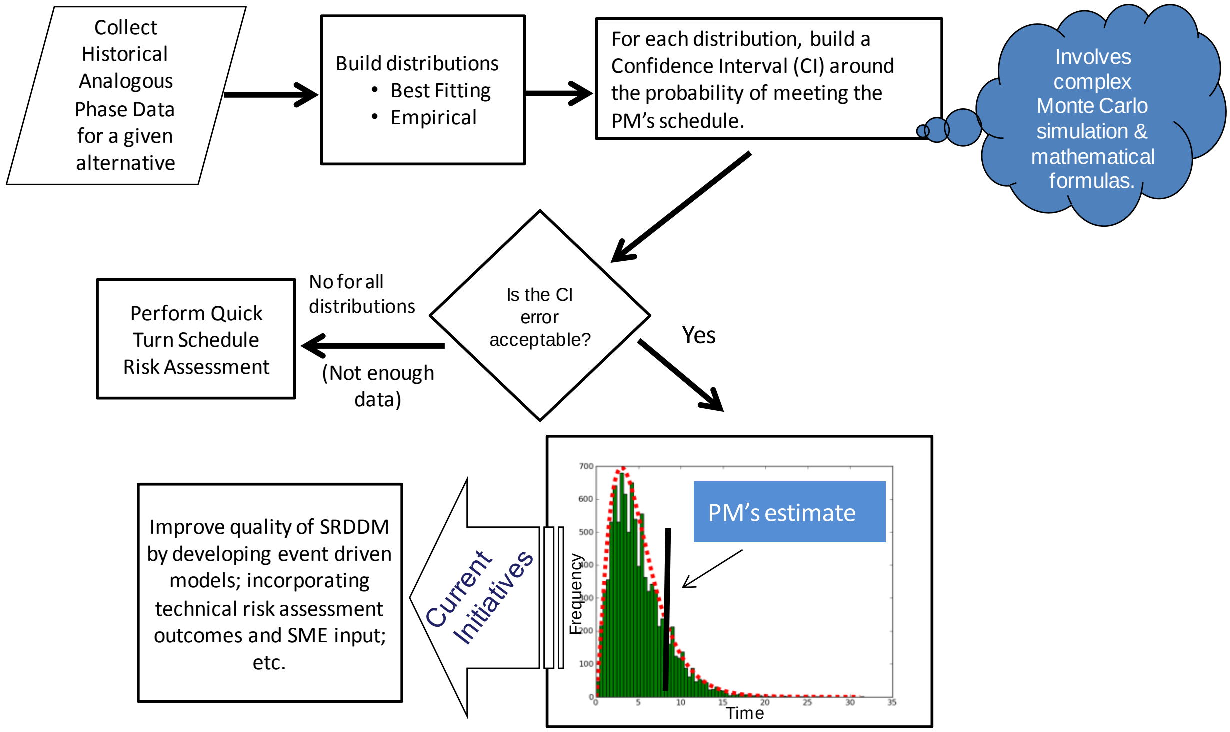



**Figure 7. SRDDM Process Flowchart**

The steps to the SRDDM process are as follows:

1. Obtain program schedule(s) from PM
2. Create initial list of historical analogous programs for each alternative
3. Obtain schedule information for analogous programs
4. Identify list of schedule risk drivers for each analogous program
5. Present analogous programs and risk drivers to stakeholders and SMEs
6. Develop consensus on analogous programs and risk drivers
7. Apply Schedule Risk Data Decision Methodology (SRDDM) to analogous program data to estimate time required to complete each acquisition phase
8. Assess schedule risk for each alternative based on estimated completion time

Steps 5-6 are accomplished during the risk workshop. For each alternative, the schedule risk assessment includes the probability of achieving each milestone date, the number of months required to reduce the risk to moderate or low, and risk drivers for analogous programs. The method for computing the probability of meeting the PM's schedule is dependent upon whether empirical data or a best fitting distribution is used. If empirical data is used, calculate the percentage of analogous data that falls below the PM's schedule estimate. If a best fitting distribution is used, calculate the area below the PM's schedule estimate. For more details on SRDDM, refer to AMSAA's technical report on the methodology.[19]

[19] Nierwinski, J., "Schedule Risk Data Decision Methodology (SRDDM)", AMSAA TR-2012-65, September 2012.

### 6.5.1 Full Schedule Risk Modeling Approach Example

Figure 8 below shows the schedule risk assessment results for a notional program. The baseline and accelerated schedules are shown at the top, and the table on the left shows the analogous programs used to conduct the notional schedule risk assessment. The cumulative probability plot on the right shows the probability and associated risk of completing the EMD phase of the baseline and accelerated schedules. The results show that the program is high risk for achieving the accelerated EMD phase time (.25) and moderate risk for achieving the baseline EMD phase time (.63). The plot also shows that a low risk EMD phase can be achieved at 45 months.

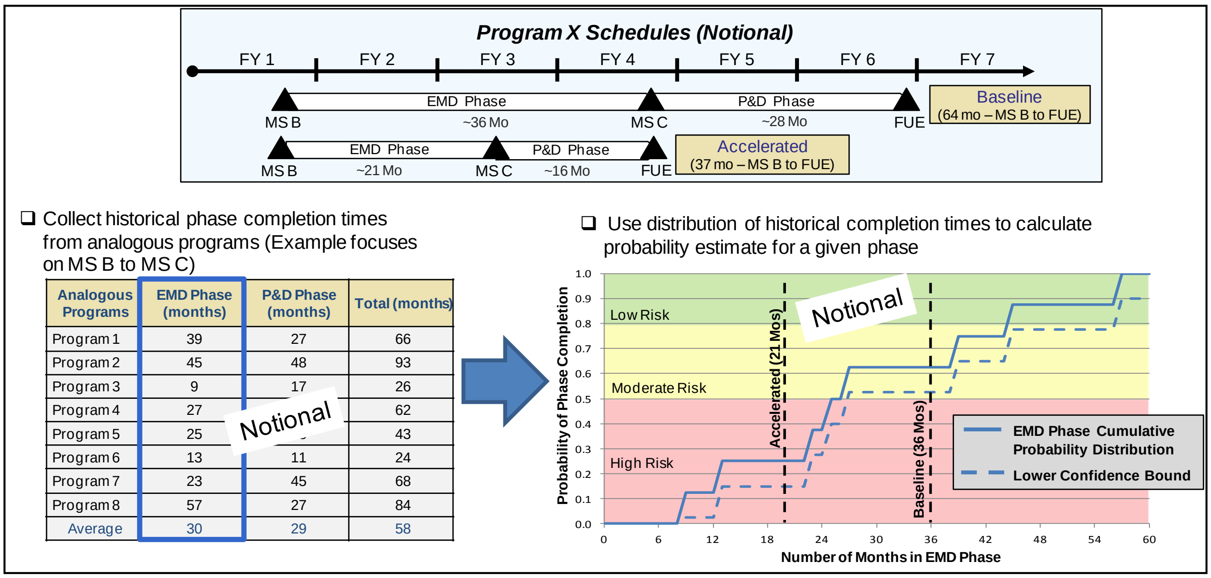



**Figure 8. Notional Schedule Risk Assessment Results**

**6.6 Data Development.** AMSAA collects historical program data from Army, Navy, Air Force and DOD sources to conduct its schedule risk assessments. Multiple data sources are utilized to collect this data, which is resource intensive. As there is no single data repository from which to obtain the required historical data and information, AMSAA has initiated development of a Historical Risk database. The database contains general, technical, and schedule data/information on current and historical programs.

During a recent schedule risk assessment application, AMSAA encountered an issue with the historical data collected. APPENDIX F –provides an explanation of the process for how the data was adjusted. This application highlighted the importance of fully understanding the data being used for schedule risk modeling.

**6.7 Data Sources.** AMSAA's schedule risk analysts rely on several data sources to provide verified, substantive schedule information for analogous programs used to support risk assessments. The current sources, and information about their content, are as follows:

- Capabilities Knowledge Base (CKB) – Provides schedule information for current and historical Army acquisition programs. Selected Acquisition Reports (SARs) collected in the database provide milestones and significant event schedule dates. In addition, these reports identify changes to the schedules and reasons for these changes. The database is operated by ODASA-CE.
- Defense Acquisition Management Information Retrieval (DAMIR) – Parent database to CKB. Provides SAR information for acquisition programs.
- Director of Operational Test & Evaluation (DOT&E) Annual Report – An online repository of DOT&E annual reports. These annual reports provide status updates of all DOD ACAT I programs. The reports are organized by year.
- Defense Technical Information Center (DTIC) online – The largest comprehensive website to search and access DOD and government-funded scientific, technical, engineering, and business-related information.
- Defense Cost and Resource Center (DCARC) Knowledge Portal – The DOD centralized repository of Earned Value Management (EVM) data.
- US Government Accountability Office (GAO) online database – Repository containing reports on DOD programs as reported by the independent, nonpartisan agency that supports Congressional operation.

**6.8 Responsibilities.** The following organizations are responsible for the schedule risk assessment:

- AMSAA: Lead the schedule risk assessment.
- PEO/PM: Provide program schedule and associated assumptions for study alternatives; provide data for analogous programs that are used in the schedule risk assessment.
- RDECs, OSD, DA G-3, Other Study Team Members: Provide data for analogous programs that are used in the schedule risk assessment.

**6.9 Schedule Risk Modeling.** The AMSAA Risk Team will continue to improve the quality of SRDDM by developing event driven models which incorporate a network of details such as: the WBS, critical path logic, correlation of events, technical risk assessment outcomes, SME input, etc. To execute and develop these event-driven models, AMSAA will work with PMs, SMEs, contractors, and any other parties that can add insight into the event-driven process. This event-driven model is called the Schedule Risk Event-Driven Methodology (SREDM). An initial version of SREDM was developed in 2013, and advancements to the methodology are currently in progress.

AMSAA intends to utilize both SRDDM and SREDM and reconcile any differences. This will produce more robust schedule risk results and provide more confidence in the final schedule risk assessment. Having two strategies to assess schedule risk may lead to more credible results and prevent the formulation of poor conclusions. For example, if SRDDM produces a high schedule risk and the event model provides a low schedule risk, reconciling the differences may reveal that a critical event was missing from the event model. Factoring this missing event element into the event model could then produce a more realistic result.

# 7. SOFTWARE RISK ASSESSMENT

**7.1 Background.** Software development is an area that can affect many DOD acquisition programs. Some programs are purely focused on the development of software-based systems while other systems utilize software components to achieve their required capability. Because of this, it is necessary to have a process set in place with which to evaluate the technical and schedule aspects of software risk within acquisition programs. The Army's schedule risk assessment methodology, previously outlined in this guidebook, may be acceptable to use when examining the risk of a software system program schedule, assuming that an appropriate set of historical analogous data can be identified. However, due to the unique nature of the technical challenges that could arise, it was determined that the technical risk assessment methodology described in this guidebook may not be suitable when considering software systems and components.

Efforts are currently underway to develop a standard Army software risk methodology that could be utilized for assessing the technical risks related to software. Development of this methodology will be done by researching methods that have been utilized in other organizations and by exploring the possibility of making modifications to the current Army risk methodologies.

The information provided in this section is meant to highlight some of the issues that could arise with applying the existing Army risk methodologies to software systems. It will also explore some potential methods for adjusting the current methodologies to accommodate software systems and components. In addition, an example of a risk assessment that AMSAA conducted on a software-based system is presented as well.

**7.2 Limitations in Applying Army Methodologies.** The technical challenges involved with software development would likely be very different than those encountered in the development of other types of systems. This is due to the fundamental differences of the components that make up software systems. For instance, the technical risk assessment methodology outlined in this guidebook examines the maturity of KTs of the system under consideration. However, a system that is software-based is typically not made up of distinct physical technologies, but rather it consists of lines of code that implement the algorithms necessary to achieve the intended functionality of the system. This code development would undergo a different type of development process than what would be utilized to mature a physical technology. As a result, the standard readiness level (TRL, MRL, and IRL) definitions may not be applicable when attempting to measure the maturity of the software system or software components. Since the technical risk methodology relies on determining the probability of achieving a particular readiness level by a certain milestone date, a standard set of software maturation levels would have to be developed and mapped to the various milestones within the acquisition lifecycle.

Given that a standard set of software maturation levels can be developed, the technical risk methodology described in this guidebook could be applied to software based systems or software components that are considered KT's of other systems. For a completely software-

based system, instead of defining a set of KT's, the software system could be decomposed into a distinct set of software sub-functions. Each of these sub-functions could then be assessed to determine their current readiness, based on the description of a software technical readiness definition. An assessment could then be made as to the time required to improve the current technical readiness level. Because the maturity of the software sub-functions would be assessed as distinct parts, it would also be necessary to examine the maturity of these sub-functions in terms of integration within the system. Further investigation can be done to determine if the IRL definitions defined previously in the guidebook would be applicable to the software sub-functions, or if a separate set of software integration readiness levels would have to be developed. Manufacturing would likely not be an area of risk that applies to software systems and components. Therefore, a software equivalent to the MRL definitions would not be necessary.

As stated previously, when attempting to analyze the risk of meeting a program schedule for a purely software-based system, the Army's schedule risk assessment methodology could be utilized if historical data on the development times of other analogous programs can be identified. Given that this information is obtainable, the methodology would be applied in the same manner as outlined in the schedule risk assessment section of this guidebook. A potential issue, however, would be in defining what is meant by analogous. To define an analogous program for a software system, a different set of criteria than what is used for non-software systems may have to be developed. Possible factors to consider for analogous comparisons may be: the functionality of the system as a whole or amongst the individual sub functions, complexity of the system and sub-functions, number of Source Lines of Code (SLOC) required, and the Capability Maturity Model Integration (CMMI) rating for the system developer. Further investigation will have to be conducted to determine which factors of analogous programs most impact the total development time of a software system.

**7.3 Software System Risk Assessment Example.** The following section discusses a process that AMSAA developed to support a recent software-based program AoA. The technical and schedule risk assessments for this AoA were combined into one risk assessment. Because this was a software-based system, the risk involved in developing the system would be largely due to the time required to write code. The risk assessment incorporated both the technical aspects of the system as well as the time to develop the system. The assessment examined the current maturity of each specific software sub-function, and used the level of maturity as a basis for determining the impact to the schedule for fully developing the sub-function.

The final risk results consisted of a set of feasibility packages, each with a specific risk level associated. A given feasibility package consisted of a sub-set of all system sub-functions. The risk level for a given feasibility package was determined by the time required to code and integrate all of the sub-functions included within the given feasibility package. In order to calculate the amount of time required to code and integrate a whole package of sub-functions, it was necessary to first determine the time involved in developing each sub-function alone. The paragraph below, along with Figure 9, describes the process that was used to determine this time.

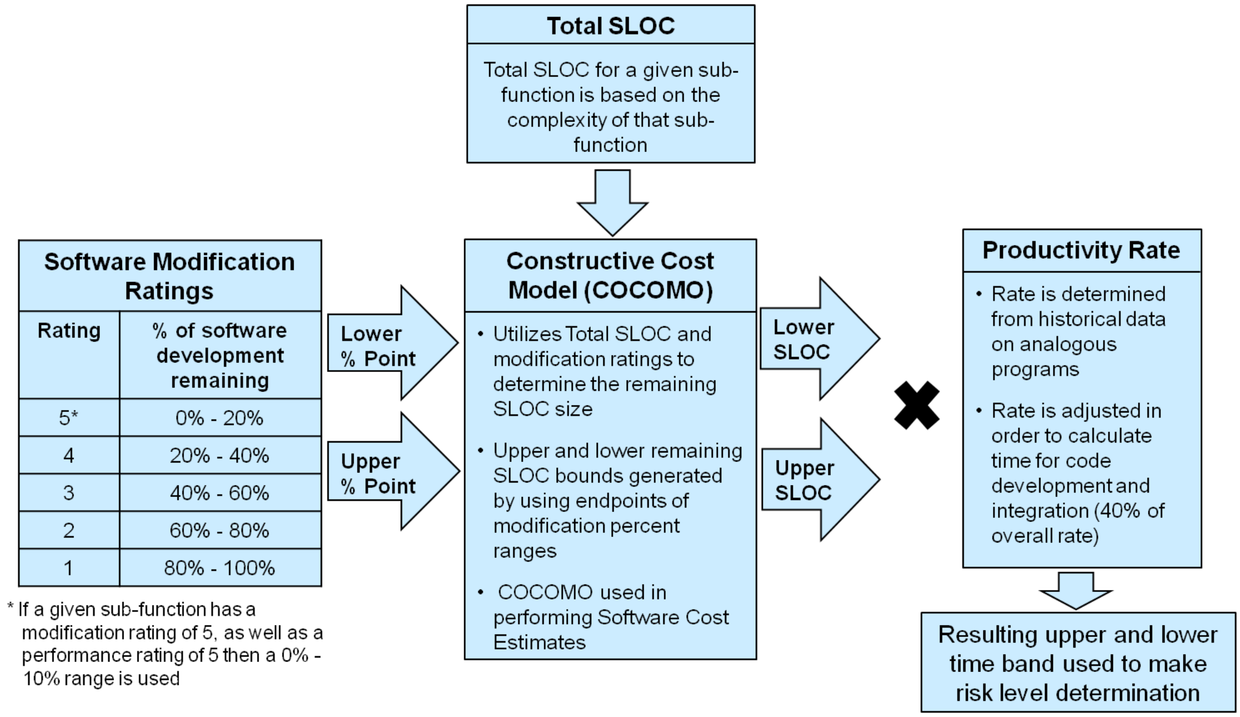



**Figure 9. Software Risk Assessment Process Flowchart**

The Constructive Cost Model (COCOMO) was used to provide an estimate of SLOC required to bring a sub-function that is either completely undeveloped or partially developed to full functionality. To calculate the remaining SLOC size, COCOMO requires both a total SLOC size and a software modification rating. The total SLOC required for a sub-function is the amount of code that is necessary in order for that sub-function to be fully developed. This amount was determined based on the complexity of the particular sub-function. Each sub-function was assigned a complexity rating of high, medium, or low. Using historical data on analogous programs, a mapping was developed that estimated a total SLOC size based on function complexity.

Each sub-function was also assigned a software modification rating. This rating was assigned based on a determination of the percent of software development remaining for the sub-function. A given rating has an upper and lower percentage bound for the amount of work remaining. For example, if a sub-function had a rating of 4, then 20% to 40% of work still remained in order to fully develop that sub-function. COCOMO uses only one percentage value to determine the remaining SLOC size. However, in order to do the risk assessment, an upper and lower calculation for remaining SLOC was necessary. As a result, COCOMO was applied twice; once using the upper percentage bound, and once using the lower percentage bound.

The upper and lower remaining SLOC values were used to calculate an upper and lower bound for time to develop the function. This was calculated by multiplying the remaining SLOC by the productivity rate. The productivity rate was given as the number of hours per SLOC (HRS/SLOC). This value was estimated based on calculated productivity rates from historical data on analogous programs.

As was mentioned previously, feasibility packages with an associated risk rating were constructed. For a given package, the risk level was determined by summing the upper and lower time bounds for all sub-functions considered, and examining where that total band fell with respect to the schedule deadline. The level of risk was assessed as low if both the upper and lower time bounds of a package fell to the left of the target date. If the target date fell in between the upper and lower time bounds, the package was assessed to be a moderate risk. If the upper and lower time bounds both fell to the right of the target date, the package was assigned a risk rating of high. The determination of risk levels is illustrated in Figure 10 below.

| Time to Complete Band Location | Risk Rating |
|---|---|
| Entire band < 7 months | Low |
| 7 months falls within band | Moderate |
| Entire band > 7 months | High |

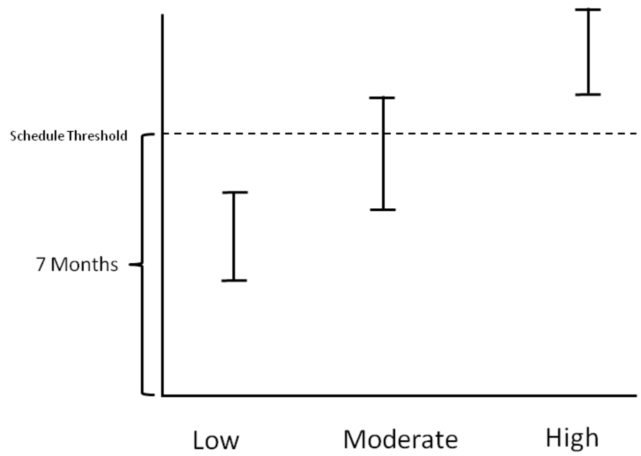



**Figure 10. Risk Level Determination**

## 8. SUMMARY

To date, 12 acquisition studies have been completed that utilized variations of the methodologies defined in this guidebook. AMSAA, with support from the Risk IPT, has numerous methodology and process improvement initiatives that are ongoing or planned. The major current initiatives include development of a Schedule Risk Event-Driven Methodology (SREDM), a Risk-Informed Trade Space Methodology (RITSM), and a Historical Risk Database. Since these methodologies may evolve over time, based on lessons learned from additional applications, and current methodology initiatives, AMSAA should be consulted to determine if any changes or improvements have been made.  This guidebook will be updated as necessary to document major methodology changes.

# APPENDIX A – TECHNOLOGY READINESS LEVEL (TRL)

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## TECHNOLOGY READINESS LEVEL (TRL)

TRL is a systematic metric/measurement system used by government agencies, including the Department of Defense, which supports assessment of the maturity of a particular technology and the consistent comparison of maturity between different types of technologies. The table below provides TRL definitions and descriptions for each level. When looking to make a readiness level assessment, consider the questions provided. If you answer 'yes' to the questions for a given TRL, the technology is likely at that TRL. If you answer 'no' to any of the questions for a given TRL, the technology is likely at a lower TRL. Continue descending on the TRL scale until you can answer 'yes' to the questions at a given TRL.

| TRL | Definition | Description | Questions to Consider |
|---|---|---|---|
| 9 | Actual system proven through successful mission operations. | Actual application of the technology in its final form and under mission conditions, such as those encountered in operational test and evaluation (OT&E). Examples include using the system under operational mission conditions. | ▪ Has the Operational Concept been implemented successfully?<br>▪ Has the actual system been fully demonstrated?<br>▪ Has the system been installed and deployed in its intended platform? |
| 8 | Actual system completed and qualified through test and demonstration. | Technology has been proven to work in its final form and under expected conditions. In almost all cases, this TRL represents the end of true system development. Examples include developmental test and evaluation (DT&E) of the system in its intended weapon system to determine if it meets design specifications. | ▪ Has the system been formed, fitted, and function designed for its intended platform?<br>▪ Has all functionality been demonstrated in simulated operational environment?<br>▪ Has the system been qualified through test and evaluation on the actual platform (DT&E completed)? |
| 7 | System prototype demonstration in an operational environment. | Prototype near or at planned operational system. Represents a major step up from TRL 6 by requiring demonstration of an actual system prototype in an operational environment (e.g., in an air-craft, in a vehicle, or in space). | ▪ Has the system been tested in an operational environment, but not the eventual platform?<br>▪ Has the system prototype been successfully tested in a field environment?<br>▪ Has M&S been used to simulate some unavailable elements of the system? |
| 6 | System/subsystem model or prototype demonstration in a relevant environment. | Representative model or prototype system, which is well beyond that of TRL 5, is tested in a relevant environment. Represents a major step up in a technology's demonstrated readiness. Examples include testing a prototype in a high-fidelity laboratory environment or in a simulated operational environment. | ▪ Has the engineering feasibility been fully demonstrated?<br>o System requirements finalized (reliability, technical, etc)?<br>o Operating environment defined?<br>▪ Has a representative model/prototype been tested in a high-fidelity lab or simulated operational environment?<br>o Relevant environment defined?<br>o Tested at relevant environment?<br>o What is the margin of safety, test to failure, sensitivity (robustness)? |

| | | | |
|---|---|---|---|
| | | | ▪ Has M&S been used to simulate system performance in an operational environment?<br>○ M&S and test correlation? |
| 5 | Component and/or breadboard validation in a relevant environment. | Fidelity of breadboard technology increases significantly. The basic technological components are integrated with reasonably realistic supporting elements so they can be tested in a simulated environment. Examples include "high-fidelity" laboratory integration of components. | ▪ Are the system interface requirements known?<br>▪ Has high fidelity lab integration of the system been completed and the system ready for test in realistic/simulated environments?<br>▪ Is the physical work breakdown structure available? |
| 4 | Component and/or breadboard validation in a laboratory environment. | Basic technological components are integrated to establish that they will work together. This is relatively "low fidelity" compared with the eventual system. Examples include integration of "ad hoc" hardware in the laboratory. | ▪ Have laboratory experiments with available components of the system show that they can work together?<br>▪ Has low fidelity system integration and engineering been completed in a lab environment?<br>▪ Has a functional work breakdown structure been developed? |
| 3 | Analytical and experimental critical function and/or characteristic proof of concept. | Active R&D is initiated. This includes analytical studies and laboratory studies to physically validate the analytical predictions of separate elements of the technology. Examples include components that are not yet integrated or representative. | ▪ Have predictions of technology capability been validated by analytical studies?<br>▪ Are paper studies available that indicate the system components ought to work together?<br>▪ Has scientific feasibility been fully demonstrated? |
| 2 | Technology concept and/or application formulated. | Invention begins. Once basic principles are observed, practical applications can be invented. Applications are speculative, and there may be no proof or detailed analysis to support the assumptions. Examples are limited to analytic studies. | ▪ Have the basic elements of the technology been identified?<br>▪ Are paper studies available that indicate the application is feasible?<br>▪ Are the experiments that need to be performed to research the technology known? |
| 1 | Basic principles observed and reported. | Lowest level of technology readiness. Scientific research begins to be translated into applied research and development (R&D). Examples might include paper studies of a technology's basic properties. | ▪ Have the physical laws and assumptions used in this technology been defined?<br>▪ Are paper studies available to confirm basic principles?<br>▪ Has a research hypothesis been formulated? |

DEFINITIONS:

BREADBOARD: Integrated components that provide a representation of a system/subsystem and which can be used to determine concept feasibility and to develop technical data. Typically configured for laboratory use to demonstrate the technical principles of immediate interest. May resemble final system/subsystem in function only.

"HIGH FIDELITY": Addresses form, fit and function. High-fidelity laboratory environment would involve testing with equipment that can simulate and validate all system specifications within a laboratory setting.

"LOW FIDELITY": A representative of the component or system that has limited ability to provide anything but first order information about the end product. Low-fidelity assessments are used to provide trend analysis.

MODEL: A functional form of a system, generally reduced in scale, near or at operational specification. Models will be sufficiently hardened to allow demonstration of the technical and operational capabilities required of the final system.

OPERATIONAL ENVIRONMENT: Environment that addresses all of the operational requirements and specifications required of the final system to include platform/packaging.

PROTOTYPE: A physical or virtual model used to evaluate the technical or manufacturing feasibility or military utility of a particular technology or process, concept, end item or system.

RELEVANT ENVIRONMENT: Testing environment that simulates the key aspects of the operational environment.

SIMULATED OPERATIONAL ENVIRONMENTAL: Either 1) a real environment that can simulate all of the operational requirements and specifications required of the final system, or 2) a simulated environment that allows for testing of a virtual prototype; used in either case to determine whether a developmental system meets the operational requirements and specifications of the final system.

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# APPENDIX B – INTEGRATION READINESS LEVEL (IRL)

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## INTEGRATION READINESS LEVEL (IRL)

IRL is a systematic measurement of the level of integration between a technology and the environment into which it will operate. The environment consists of various physical systems (electrical, mechanical, hydraulic, informational, etc), other technologies, functional groups such as manufacturing and service, regulations, military standards, test environments, etc. Adequate interfaces between the technology and environment are required to meet overall system performance requirements. The IRL provides an indicator of the level of accountability of these interfaces affecting technology implementation. IRL is not yet an approved DOD measure. It was developed by the Stevens Institute of Technology, with modifications made by TARDEC for use in Army Risk Assessments. The table below provides IRL definitions and descriptions for each level. When looking to make a readiness level assessment, consider the questions provided. If you answer 'yes' to the questions for a given IRL, the technology is likely at that IRL. If you answer 'no' to any of the questions for a given IRL, the technology is likely at a lower IRL. Continue descending on the IRL scale until you can answer 'yes' to the questions at a given IRL.

| IRL | Definition | Description | Questions to Consider |
|---|---|---|---|
| 9 | Actual integration completed and Mission Qualified through test and demonstration in the system environment. | Product design features and configuration are stable. System design has been validated through operational testing of Low Rate Initial Production (LRIP) items. Physical Configuration Audit (PCA) or equivalent complete as necessary. Design freeze is in place. All changes require formal Engineering Change Proposal (ECP) approval process. All key characteristics (KCs) are controlled in LRIP to threshold quality levels. All component, element, assembly and subsystem specifications have been demonstrated to be satisfied in a repeatable fashion in the mass production facilities using specified materials, process, machinery, equipment and tooling. | ▪ Has a fully integrated system demonstrated operational effectiveness and suitability in its intended or a representative operational environment?<br>▪ Have interface failures/failure rates been fully characterized and consistent with user requirements? |
| 8 | Functionality of integration technology has been demonstrated in prototype modified vehicles. | Detailed design of product features and interfaces is complete. All product data essential for system manufacturing has been released. Design changes do not significantly impact LRIP. KCs are attainable based upon pilot line demonstrations. Component and element specifications have been established and been agreed to by configuration item (CI) component and platform integrating manufacturers. Functionality of integration items has been demonstrated in prototype modified vehicles. | ▪ Are all integrated systems able to meet overall system requirements in an operational environment?<br>▪ Have system interfaces been qualified and functioning correctly in an operational environment?<br>▪ Has integration testing been closed out with test results, anomalies, deficiencies and corrective actions documented? |

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| 7 | Technology integration has been verified and validated with sufficient detail to be actionable. | Product requirements and features are well enough defined to support critical design review, even though design changes may be significant. All product data essential for component manufacturing has been released. Potential KC risk issues have been identified and mitigation plan is in place. Full prototype integration CIs have been successfully integrated and shown to have functional requirement compliance in system integration labs (SILs). | ▪ Has end-to-end functionality of the systems integration been successfully demonstrated?<br>▪ Has each system interface been tested individually under stressed and anomalous conditions?<br>▪ Has the fully integrated prototype been demonstrated in actual or simulated operational environments? |
| 6 | Integration element baseline established. | Integration element baseline established; platform interfaces have all been identified and agreed to. All enabling/key technologies/components for the integration CIs have been demonstrated. Preliminary design KCs defined. Notional interface proposals with constraints have been established (mechanical, all required vehicle modifications to accept technologies to be integrated, electrical/cabling, wireless protocol, security, human interface etc.). The integrating technologies can Accept, Translate, and Structure Information for its intended application. | ▪ Have individual systems been tested to verify that the system components work together?<br>▪ Have integrated system demonstrations been successfully completed?<br>▪ External interfaces established (hardware, software, physical interfaces, and functional interfaces)?<br>▪ Interface analysis?<br>▪ Test requirements of interfacing systems and acceptance criteria?<br>▪ Met all interfacing requirements by tests or analysis (systems work together)? |
| 5 | Major integrating technology functions demonstrated with prototypes, engineering models or in laboratories. | Lower level performance requirements sufficient to proceed to preliminary design. All enabling/key technologies and components identified and consider the product lifecycle. Evaluation of design KCs initiated. Product data required for prototype component manufacturing released. Major functions of the integrating technology have been demonstrated with prototypes, engineering models or in laboratories. There is sufficient Control between technologies necessary to establish, manage, and terminate the integration. | ▪ Has an Interface Control Plan been implemented (i.e. Interface Control Document created, Interface Control Working Group formed, etc.)?<br>▪ Are external interfaces well defined (i.e. source, data formats, structure, content, method of support, etc.)?<br>▪ Have system interface requirements specification been drafted? |

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| 4 | There is sufficient detail in the quality and assurance of the integration technologies. | Integrating technologies have proposed interfaces established for a targeted platform for a proposed technology insertion or a SIL. Initial potential Key Performance Parameters (KPPs) identified for preferred systems concept. Integration CI characteristics and measures to support required capabilities identified. Form, fit, and function constraints identified and manufacturing capabilities identified for integration CIs. Limited functionality for integration elements has been demonstrated via simulation, or a preliminary integration scheme has been implemented to permit collection of integration technology performance data in a laboratory. | ▪ Are overall system requirements for end users' application known/baselined?<br>▪ Have analyses or internal interface requirements been completed?<br>▪ Has a rigorous requirements inspection process been implemented? |
| 3 | Integration features for integration technology elements have been modeled. | Top level performance requirements defined. Trade-offs in design options assessed based on models. Product lifecycle and technical requirements evaluated. Integration features for integration technology elements have been modeled. There is compatibility (i.e., common language) between technologies to orderly and efficiently integrate and interact. | ▪ Have high-level system interface diagrams been completed?<br>▪ Are the interface requirements defined at the concept level? |
| 2 | There is some level of specificity to characterize technology interaction (i.e., ability to influence) between technologies through their interface. | Applications defined. Broad performance goals identified. Proposed configuration concepts developed and modeled enough for "Proof of Concept" for the integration technology. Some generalized integration CI interface schemes have been proposed. | ▪ Are the inputs/outputs for principal integration technologies known, characterized and documented?<br>▪ Have the principal interface requirements for integration technologies been defined/drafted? |
| 1 | An interface has been identified with sufficient detail to allow characterization of the technology relationship. | Interfaces between technologies have been identified. Capabilities exist to provide a solution for a need, but little consideration has been given to potential applications and integration schemes. | ▪ Have the principal integration technologies been identified?<br>▪ Have the top-level functional architecture and interface points been defined?<br>▪ Is the availability of principal integration technologies known and documented? |

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# APPENDIX C – MANUFACTURING READINESS LEVEL (MRL)

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## MANUFACTURING READINESS LEVEL (MRL)

MRL is a systematic metric/measurement system that supports assessment of the maturity of a given technology, component or system from a manufacturing perspective. The table below provides MRL definitions and descriptions for each level. When looking to make a readiness level assessment, consider the questions provided. If you answer 'yes' to the questions for a given MRL, the technology is likely at that MRL. If you answer 'no' to any of the questions for a given MRL, the technology is likely at a lower MRL. Continue descending on the MRL scale until you can answer 'yes' to the questions at a given MRL.

| MRL | Definition | Description | Questions to Consider |
|---|---|---|---|
| 10 | Full Rate Production demonstrated and lean production practices in place. | This is the highest level of production readiness. Technologies should have matured to TRL 9. This level of manufacturing is normally associated with the Production or Sustainment phases of the acquisition life cycle. Engineering/design changes are few and generally limited to quality and cost improvements. System, components or items are in full rate production and meet all engineering, performance, quality and reliability requirements. Manufacturing process capability is at the appropriate quality level. All materials, tooling, inspection and test equipment, facilities and manpower are in place and have met full rate production requirements. Rate production unit costs meet goals, and funding is sufficient for production at required rates. Lean practices are well established and continuous process improvements are ongoing. | ▪ Does industrial capability support FRP?<br>▪ Is the product design stable?<br>▪ Are manufacturing processes stable, adequately controlled, capable, and achieve program FRP objectives?<br>▪ Are production facilities in place and capacity demonstrated to meet maximum FRP requirements? |
| 9 | Low rate production demonstrated; Capability in place to begin Full Rate Production. | At this level, the system, component or item has been previously produced, is in production, or has successfully achieved low rate initial production. Technologies should have matured to TRL 9. This level of readiness is normally associated with readiness for entry into Full Rate Production (FRP). All systems engineering/design requirements should have been met such that there are minimal system changes. Major system design features are stable and have been proven in test and evaluation. Materials are available to meet planned rate production schedules. Manufacturing process capability in a low rate production | ▪ Is industrial capability in place to support start of FRP?<br>▪ Are major product design features and configuration designs stable?<br>▪ Are manufacturing processes stable, adequately controlled, capable, and achieve program LRIP objectives?<br>▪ Are manufacturing facilities in place and demonstrated in LRIP? |

| | | | |
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| | | environment is at an appropriate quality level to meet design key characteristic tolerances. Production risk monitoring is ongoing. LRIP cost targets have been met, and learning curves have been analyzed with actual data. The cost model has been developed for FRP environment and reflects the impact of continuous improvement. | |
| 8 | Pilot line capability demonstrated; Ready to begin Low Rate Initial Production. | This level is associated with readiness for a Milestone C decision, and entry into Low Rate Initial Production (LRIP). Technologies should have matured to at least TRL 7. Detailed system design is complete and sufficiently stable to enter low rate production. All materials, manpower, tooling, test equipment and facilities are proven on pilot line and are available to meet the planned low rate production schedule. Manufacturing and quality processes and procedures have been proven in a pilot line environment and are under control and ready for low rate production. Known producibility risks pose no significant challenges for low rate production. Cost model and yield and rate analyses have been updated with pilot line results. Supplier qualification testing and first article inspection have been completed. The Industrial Capabilities Assessment for Milestone C has been completed and shows that the supply chain is established to support LRIP. | ▪ Has the Industrial Capability Assessment (ICA) for MS C been completed?<br>▪ Has a detailed design of product features and interfaces been completed?<br>▪ Have manufacturing processes been verified for LRIP on a pilot line?<br>▪ Have pilot line facilities been demonstrated? |
| 7 | Capability to produce systems, subsystems, or components in a production representative environment. | This level of manufacturing readiness is typical for the mid-point of the Engineering and Manufacturing Development (EMD) Phase leading to the Post-CDR Assessment. Technologies should be on a path to achieve TRL 7.System detailed design activity is nearing completion. Material specifications have been approved and materials are available to meet the planned pilot line build schedule. Manufacturing processes and procedures have been demonstrated in a production representative environment. Detailed producibility trade studies are completed and producibility enhancements and risk assessments are underway. The cost model has been | ▪ Has industrial capability to support production been analyzed?<br>▪ Have product requirements and features been well enough defined to support critical design review, even though design changes may be significant?<br>▪ Have manufacturing processes been demonstrated in a production representative environment?<br>▪ Have manufacturing facilities been identified and plans developed to produce LRIP build? |

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| | | updated with detailed designs, rolled up to system level, and tracked against allocated targets. | |
| 6 | Capability to produce a prototype system or subsystem in a production relevant environment. | Unit cost reduction efforts have been prioritized and are underway. Yield and rate analyses have been updated with production representative data. The supply chain and supplier quality assurance have been assessed and long-lead procurement plans are in place. Manufacturing plans and quality targets have been developed. Production tooling and test equipment design and development have been initiated. | ▪ Has the ICA for MS B been completed?<br>▪ Has the system allocated baseline been established?<br>▪ Have the manufacturing processes been demonstrated in a production relevant environment?<br>○ Pre-production hardware built to same level of quality?<br>○ Quality level established?<br>○ Critical manufacturing processes prototyped?<br>▪ Have the manufacturing facilities been identified and plans been developed to produce pilot line build? |
| 5 | Capability to produce prototype components in a production relevant environment. | This level of maturity is typical of the mid-point in the Technology Development Phase of acquisition, or in the case of key technologies, near the mid-point of an Advanced Technology Demonstration (ATD) project. Technologies should have matured to at least TRL 5. The industrial base has been assessed to identify potential manufacturing sources. A manufacturing strategy has been refined and integrated with the risk management plan. Identification of enabling/key technologies and components is complete. Prototype materials, tooling and test equipment, as well as personnel skills have been demonstrated on components in a production relevant environment, but many manufacturing processes and procedures are still in development. Manufacturing technology development efforts have been initiated or are ongoing. Producibility assessments of key technologies and components are ongoing. A cost model has been constructed to assess projected manufacturing cost. | ▪ Has an industrial base assessment been initiated to identify potential manufacturing sources?<br>▪ Are lower level performance requirements sufficient to proceed to preliminary design?<br>▪ Has maturity been assessed on similar processes in production?<br>▪ Have manufacturing facilities been identified and plans been developed to produce prototypes? |
| 4 | Capability to produce the technology in a laboratory environment. | This level of readiness acts as an exit criterion for the Materiel Solution Analysis (MSA) Phase approaching a Milestone A decision. Technologies should have matured to at least TRL 4. This level indicates that the | ▪ Have industrial base capabilities been surveyed and known gaps/risks identified for preferred concept, key technologies, components, and/or key processes? |

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| | | technologies are ready for the Technology Development Phase of acquisition. At this point, required investments, such as manufacturing technology development, have been identified. Processes to ensure manufacturability, producibility, and quality are in place and are sufficient to produce technology demonstrators. | ▪ Have form, fit, and function constraints been identified and manufacturing capabilities identified for preferred systems concepts?<br>▪ Has a survey to determine the current state of critical processes been completed?<br>▪ Has the availability of manufacturing facilities for prototype development and production been evaluated? |
| 3 | Manufacturing Proof of Concept Developed. | Manufacturing risks have been identified for building prototypes and mitigation plans are in place. Target cost objectives have been established and manufacturing cost drivers have been identified. Producibility assessments of design concepts have been completed. Key design performance parameters have been identified as well as any special tooling, facilities, material handling and skills required. | ▪ Have potential sources been identified for technology needs?<br>▪ Have top level performance requirements been defined?<br>▪ Have high level manufacturing processes been documented?<br>▪ Have specialized facility requirements/needs been identified? |
| 2 | Manufacturing Concepts Identified. | This level is characterized by describing the application of new manufacturing concepts. Applied research translates basic research into solutions for broadly defined military needs. Typically this level of readiness includes identification, paper studies and analysis of material and process approaches. An understanding of manufacturing feasibility and risk is emerging. | ▪ Have broad performance goals been identified that may drive manufacturing options?<br>▪ Have materials and/or process approaches been identified? |
| 1 | Basic Manufacturing Implications Identified. | The focus is to address manufacturing shortfalls and opportunities needed to achieve program objectives. Basic research (i.e., funded by budget activity) begins in the form of studies. | ▪ Have manufacturing research opportunities been identified? |

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# APPENDIX D – SAMPLE RDEC TECHNICAL RISK ASSESSMENT GUIDANCE

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## SAMPLE RDEC TECHNICAL RISK ASSESSMENT GUIDANCE

**ANALYSIS OF ALTERNATIVES (AoA)**
**TECHNICAL RISK ASSESSMENT**

**RESEARCH, DEVELOPMENT & ENGINEERING CENTER (RDEC)**
**SUBJECT MATTER EXPERT (SME) GUIDANCE**

**TECHNOLOGY: ______________________________________________________________**
**SME (NAME, PHONE, EMAIL):__________________________________________________**
**SCOPE:** TARDEC is performing a technical risk assessment in support of the XXXX AoA. The technical risk assessment encompasses the following:

- Collection of historical technical data for technologies.
- Identification of key technologies.
- Assessment of technology maturity, integration and manufacturing readiness for key technologies and technologies of interest.
- Identification and assessment of risks.

PM, XXXX has provided historical technical data for the technologies. You are requested to determine if the technology is a key technology, assign a technology readiness level (TRL), an integration readiness level (IRL) and a manufacturing level (MRL) and identify any technical risks and mitigation steps if known. The assessment of the risks will be performed at a risk workshop and is not a required action by you at this time.

**INSTRUCTIONS:** Read this document in its entirety.

### 1) Review Data and Traceability Information

Review data related to your technology and the alternative. For requirements related information, reference the provided CDD requirements and links to performance specifications. You may also want to consider talking to other groups that may have integrated your technology on their program to gather additional information pertaining to readiness levels and risks. Determine if you have enough information to perform items 2 – 6 listed below. If yes, continue to item 2. If no, contact the PM, XXXX SME or the candidate system POC.

### 2) Key Technologies

Identify the key technologies (KTs) from the list of technologies under consideration. KTs should be determined similarly to guidance in Army TRA Guidance (June 2011) for determining whether or not a technology is key.[20] The criteria used to assess key technologies are as follows:

1. First, does the technology pose major technological risk during development?
2. Second, does the system depend on this technology to meet Key Performance Parameters (KPP), Key System Attributes (KSA), or designed performance?
3. Third, is the technology or its application new or novel or is the technology modified beyond design intent?

If the answer to question 1 is ‘Yes’, then the technology is key. If the answer to both questions 2 AND 3 are ‘Yes’, then the technology is also key.

[20] Army Technology Readiness Assessment Guidance, Deputy Assistant Secretary of Army for Research and Technology (DASA(R&T)), June 2011.

It is not enough to state that a particular technology is classified as key. A rationale explaining why the technology has been identified as a KT is required and must be provided by each technology SME.
:

Determine if the technology is a key technology and provide rationale in the table provided below.

| Technology | Is this a key technology? Answer yes or no. | Rationale |
|---|---|---|
| | | |

## 3) Technology Readiness Level (TRL)

The table below provides TRL definitions and descriptions for each level. Also consider the questions provided. If you answer yes to the questions for a given TRL, the technology is likely at that TRL. If you answer no to any of the questions for a given TRL, the technology is likely at a lower TRL. Continue descending on the TRL scale until you can answer yes to the questions at a given TRL.

| TRL | Definition | Description | Questions to Consider |
|---|---|---|---|
| 9 | Actual system proven through successful mission operations. | Actual application of the technology in its final form & under mission conditions, such as those encountered in operational test & evaluation (OT&E). Examples include using the system under operational mission conditions. | ▪ Has the Operational Concept been implemented successfully?<br>▪ Has the actual system been fully demonstrated?<br>▪ Has the system been installed & deployed in its intended platform? |
| 8 | Actual system completed & qualified through test & demonstration. | Technology has been proven to work in its final form & under expected conditions. In almost all cases, this TRL represents the end of true system development. Examples include developmental test & evaluation (DT&E) of the system in its intended weapon system to determine if it meets design specifications. | ▪ Has the system been formed, fitted, & function designed for its intended platform?<br>▪ Has all functionality been demonstrated in simulated operational environment?<br>▪ Has the system been qualified through test & evaluation on the actual platform (DT&E completed)? |
| 7 | System prototype demonstration in an operational environment. | Prototype near or at planned operational system. Represents a major step up from TRL 6 by requiring demonstration of an actual system prototype in an operational environment (e.g., in an air-craft, in a vehicle, or in space). | ▪ Has the system been tested in an operational environment, but not the eventual platform?<br>▪ Has the system prototype been successfully tested in a field environment?<br>▪ Has M&S been used to simulate some unavailable elements of the system? |
| 6 | System/subsystem model or prototype demonstration in a relevant environment. | Representative model or prototype system, which is well beyond that of TRL 5, is tested in a relevant environment. Represents a major step up in a technology's demonstrated readiness. | ▪ Has the engineering feasibility been fully demonstrated?<br>o System requirements finalized (reliability, technical, etc)?<br>o Operating environment defined? |

| | | | |
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| | | Examples include testing a prototype in a high-fidelity laboratory environment or in a simulated operational environment. | ▪ Has a representative model/prototype been tested in a high-fidelity lab or simulated operational environment?<br>o Relevant environment defined?<br>o Tested at relevant environment?<br>o What is the margin of safety, test to failure, sensitivity (robustness)?<br>▪ Has M&S been used to simulate system performance in an operational environment?<br>o M&S & test correlation? |
| 5 | Component &/or breadboard validation in a relevant environment. | Fidelity of breadboard technology increases significantly. The basic technological components are integrated with reasonably realistic supporting elements so they can be tested in a simulated environment. Examples include "high-fidelity" laboratory integration of components. | ▪ Are the system interface requirements known?<br>▪ Has high fidelity lab integration of the system been completed & the system ready for test in realistic/simulated environments?<br>▪ Is the physical work breakdown structure available? |
| 4 | Component &/or breadboard validation in a laboratory environment. | Basic technological components are integrated to establish that they will work together. This is relatively "low fidelity" compared with the eventual system. Examples include integration of "ad hoc" hardware in the laboratory. | ▪ Have laboratory experiments with available components of the system show that they can work together?<br>▪ Has low fidelity system integration & engineering been completed in a lab environment?<br>▪ Has a functional work breakdown structure been developed? |
| 3 | Analytical & experimental critical function &/or characteristic proof of concept. | Active R&D is initiated. This includes analytical studies & laboratory studies to physically validate the analytical predictions of separate elements of the technology. Examples include components that are not yet integrated or representative. | ▪ Have predictions of technology capability been validated by analytical studies?<br>▪ Are paper studies available that indicate the system components ought to work together?<br>▪ Has scientific feasibility been fully demonstrated? |
| 2 | Technology concept &/or application formulated. | Invention begins. Once basic principles are observed, practical applications can be invented. Applications are speculative, & there may be no proof or detailed analysis to support the assumptions. Examples are limited to analytic studies. | ▪ Have the basic elements of the technology been identified?<br>▪ Are paper studies available that indicate the application is feasible?<br>▪ Are the experiments that need to be performed to research the technology known? |
| 1 | Basic principles observed & reported. | Lowest level of technology readiness. Scientific research begins to be translated into applied research & development (R&D). Examples might include paper | ▪ Have the physical laws & assumptions used in this technology been defined?<br>▪ Are paper studies available to confirm basic principles? |

| | | | |
|---|---|---|---|
| | | studies of a technology's basic properties. | ▪ Has a research hypothesis been formulated? |

Assign current TRL and provide rationale for rating in the table provided below.

| Technology | TRL | Rationale |
|---|---|---|
| | | |

## 4) Integration Readiness Level (IRL)

The table below provides IRL definitions and descriptions for each level. Also consider the questions provided. If you answer yes to the questions for a given IRL, the technology is likely at that IRL. If you answer no to any of the questions for a given IRL, the technology is likely at a lower IRL. Continue descending on the IRL scale until you can answer yes to the questions at a given IRL.

| IRL | Definition | Description | Questions to Consider |
|---|---|---|---|
| 9 | Actual integration completed and Mission Qualified through test and demonstration in the system environment. | Product design features and configuration are stable. System design has been validated through operational testing of LRIP items. Physical Configuration Audit (PCA) or equivalent complete as necessary. Design freeze is in place. All changes require formal Engineering Change Proposal (ECP) approval process. All KCs are controlled in LRIP to threshold quality levels. All component, element, assembly and subsystem specifications have been demonstrated to be satisfied in a repeatable fashion in the mass production facilities using specified materials, process, machinery, equipment and tooling. | ▪ Has a fully integrated system demonstrated operational effectiveness and suitability in its intended or a representative operational environment?<br>▪ Have interface failures/failure rates been fully characterized and consistent with user requirements? |
| 8 | Functionality of integration technology has been demonstrated in prototype modified vehicles. | Detailed design of product features and interfaces is complete. All product data essential for system manufacturing has been released. Design changes do not significantly impact Low Rate Initial Production (LRIP). KCs are attainable based upon pilot line demonstrations. Component and element specifications have been established and been agreed to by CI component and platform integrating manufacturers. Functionality of integration items has been demonstrated in prototype modified vehicles. | ▪ Are all integrated systems able to meet overall system requirements in an operational environment?<br>▪ Have system interfaces been qualified and functioning correctly in an operational environment?<br>▪ Has integration testing been closed out with test results, anomalies, deficiencies and corrective actions documented? |

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| 7 | Technology integration has been verified and validated with sufficient detail to be actionable. | Product requirements and features are well enough defined to support critical design review, even though design changes may be significant. All product data essential for component manufacturing has been released. Potential KC risk issues have been identified and mitigation plan is in place. Full prototype integration CIs have been successfully integrated and shown to have functional requirement compliance in SILs. | ▪ Has end-to-end functionality of the systems integration been successfully demonstrated?<br>▪ Has each system interface been tested individually under stressed and anomalous conditions?<br>▪ Has the fully integrated prototype been demonstrated in actual or simulated operational environments? |
| 6 | Integration element baseline established. | Integration element baseline established; platform interfaces have all been identified and agreed to. All enabling/key technologies/components for the integration CIs have been demonstrated. Preliminary design KCs defined. Notional interface proposals with constraints have been established (mechanical, all required vehicle modifications to accept technologies to be integrated, electrical/cabling, wireless protocol, security, human interface etc.). The integrating technologies can Accept, Translate, and Structure Information for its intended application. | ▪ Have individual systems been tested to verify that the system components work together?<br>▪ Have integrated system demonstrations been successfully completed?<br>▪ External interfaces established (hardware, software, physical interfaces, and functional interfaces)?<br>▪ Interface analysis?<br>▪ Test requirements of interfacing systems and acceptance criteria?<br>▪ Met all interfacing requirements by tests or analysis (systems work together)? |
| 5 | Major integrating technology functions demonstrated with prototypes, engineering models or in laboratories. | Lower level performance requirements sufficient to proceed to preliminary design. All enabling/key technologies and components identified and consider the product lifecycle. Evaluation of design Key Characteristics (KC) initiated. Product data required for prototype component manufacturing released. Major functions of the integrating technology have been demonstrated with prototypes, engineering models or in laboratories. There is sufficient Control between technologies necessary to establish, manage, and terminate the integration. | ▪ Has an Interface Control Plan been implemented (i.e. Interface Control Document created, Interface Control Working Group formed, etc.)?<br>▪ Are external interfaces well defined (i.e. source, data formats, structure, content, method of support, etc.)?<br>▪ Have system interface requirements specification been drafted? |
| 4 | There is sufficient detail in the quality | Integrating technologies have proposed interfaces established for a targeted | ▪ Are overall system requirements for end users' application known/baselined? |

| | | | |
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| | and assurance of the integration technologies. | platform for a proposed technology insertion or a Systems Integration Lab (SIL). Initial potential Key Performance Parameters (KPPs) identified for preferred systems concept. Integration CI characteristics and measures to support required capabilities identified. Form, fit, and function constraints identified and manufacturing capabilities identified for integration CIs. Limited functionality for integration elements has been demonstrated via simulation, or a preliminary integration scheme has been implemented to permit collection of integration technology performance data in a laboratory. | ▪ Have analyses or internal interface requirements been completed?<br>▪ Has a rigorous requirements inspection process been implemented? |
| 3 | Integration features for integration technology elements have been modeled. | Top level performance requirements defined. Trade-offs in design options assessed based on models. Product lifecycle and technical requirements evaluated. Integration features for integration technology elements have been modeled. There is compatibility (i.e., common language) between technologies to orderly and efficiently integrate and interact. | ▪ Have high-level system interface diagrams been completed?<br>▪ Are the interface requirements defined at the concept level? |
| 2 | There is some level of specificity to characterize technology interaction (i.e., ability to influence) between technologies through their interface. | Applications defined. Broad performance goals identified. Proposed configuration concepts developed and modeled enough for "Proof of Concept" for the integration technology. Some generalized integration Configuration Item (CI) interface schemes have been proposed. | ▪ Are the inputs/outputs for principal integration technologies known, characterized and documented?<br>▪ Have the principal interface requirements for integration technologies been defined/drafted? |
| 1 | An interface has been identified with sufficient detail to allow characterization of the technology relationship. | Interfaces between technologies have been identified. Capabilities exist to provide a solution for a need, but little consideration has been given to potential applications and integration schemes. | ▪ Have the principal integration technologies been identified?<br>▪ Have the top-level functional architecture and interface points been defined?<br>▪ Is the availability of principal integration technologies known and documented? |

Assign current IRL and provide rationale for rating in the table provided below.

| Technology | IRL | Rationale |
|---|---|---|
| | | |

## 5) Manufacturing Readiness Level (MRL)

The table below provides MRL definitions and descriptions for each level. Also consider the questions provided. If you answer yes to the questions for a given MRL, the technology is likely at that MRL. If you answer no to any of the questions for a given MRL, the technology is likely at a lower MRL. Continue descending on the MRL scale until you can answer yes to the questions at a given MRL.

| MRL | Definition | Description | Questions to Consider |
|---|---|---|---|
| 10 | Full Rate Production demonstrated and lean production practices in place. | This is the highest level of production readiness. Technologies should have matured to TRL 9. This level of manufacturing is normally associated with the Production or Sustainment phases of the acquisition life cycle. Engineering/design changes are few and generally limited to quality and cost improvements. System, components or items are in full rate production and meet all engineering, performance, quality and reliability requirements. Manufacturing process capability is at the appropriate quality level. All materials, tooling, inspection and test equipment, facilities and manpower are in place and have met full rate production requirements. Rate production unit costs meet goals, and funding is sufficient for production at required rates. Lean practices are well established and continuous process improvements are ongoing. | ▪ Does industrial capability support FRP?<br>▪ Is the product design stable?<br>▪ Are manufacturing processes stable, adequately controlled, capable, and achieve program FRP objectives?<br>▪ Are production facilities in place and capacity demonstrated to meet maximum FRP requirements? |
| 9 | Low rate production demonstrated; Capability in place to begin Full Rate Production. | At this level, the system, component or item has been previously produced, is in production, or has successfully achieved low rate initial production. Technologies should have matured to TRL 9. This level of readiness is normally associated with readiness for entry into Full Rate Production (FRP). All systems engineering/design requirements should have been met such that there are minimal system changes. Major system design features | ▪ Is industrial capability in place to support start of FRP?<br>▪ Are major product design features and configuration designs stable?<br>▪ Are manufacturing processes stable, adequately controlled, capable, and achieve program LRIP objectives?<br>▪ Are manufacturing facilities in place and demonstrated in LRIP? |

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| | | are stable and have been proven in test and evaluation. Materials are available to meet planned rate production schedules. Manufacturing process capability in a low rate production environment is at an appropriate quality level to meet design key characteristic tolerances. Production risk monitoring is ongoing. LRIP cost targets have been met, and learning curves have been analyzed with actual data. The cost model has been developed for FRP environment and reflects the impact of continuous improvement. | |
| 8 | Pilot line capability demonstrated; Ready to begin Low Rate Initial Production. | This level is associated with readiness for a Milestone C decision, and entry into Low Rate Initial Production (LRIP). Technologies should have matured to at least TRL 7. Detailed system design is complete and sufficiently stable to enter low rate production. All materials, manpower, tooling, test equipment and facilities are proven on pilot line and are available to meet the planned low rate production schedule. Manufacturing and quality processes and procedures have been proven in a pilot line environment and are under control and ready for low rate production. Known producibility risks pose no significant challenges for low rate production. Cost model and yield and rate analyses have been updated with pilot line results. Supplier qualification testing and first article inspection have been completed. The Industrial Capabilities Assessment for Milestone C has been completed and shows that the supply chain is established to support LRIP. | ▪ Has the Industrial Capability Assessment (ICA) for MS C been completed?<br>▪ Has a detailed design of product features and interfaces been completed?<br>▪ Have manufacturing processes been verified for LRIP on a pilot line?<br>▪ Have pilot line facilities been demonstrated? |
| 7 | Capability to produce systems, subsystems, or components in a production representative environment. | This level of manufacturing readiness is typical for the mid-point of the Engineering and Manufacturing Development (EMD) Phase leading to the Post-CDR Assessment. Technologies should be on a path to achieve TRL 7.System detailed design activity is nearing completion. Material specifications have been approved and | ▪ Has industrial capability to support production been analyzed?<br>▪ Have product requirements and features been well enough defined to support critical design review, even though design changes may be significant?<br>▪ Have manufacturing processes |

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| | | materials are available to meet the planned pilot line build schedule. Manufacturing processes and procedures have been demonstrated in a production representative environment. Detailed producibility trade studies are completed and producibility enhancements and risk assessments are underway. The cost model has been updated with detailed designs, rolled up to system level, and tracked against allocated targets. | been demonstrated in a production representative environment?<br>▪ Have manufacturing facilities been identified and plans developed to produce LRIP build? |
| 6 | Capability to produce a prototype system or subsystem in a production relevant environment. | Unit cost reduction efforts have been prioritized and are underway. Yield and rate analyses have been updated with production representative data. The supply chain and supplier quality assurance have been assessed and long-lead procurement plans are in place. Manufacturing plans and quality targets have been developed. Production tooling and test equipment design and development have been initiated. | ▪ Has the ICA for MS B been completed?<br>▪ Has the system allocated baseline been established?<br>▪ Have the manufacturing processes been demonstrated in a production relevant environment?<br>o Pre-production hardware built to same level of quality?<br>o Quality level established?<br>o Critical manufacturing processes prototyped?<br>▪ Have the manufacturing facilities been identified and plans been developed to produce pilot line build? |
| 5 | Capability to produce prototype components in a production relevant environment. | This level of maturity is typical of the mid-point in the Technology Development Phase of acquisition, or in the case of key technologies, near the mid-point of an Advanced Technology Demonstration (ATD) project. Technologies should have matured to at least TRL 5. The industrial base has been assessed to identify potential manufacturing sources. A manufacturing strategy has been refined and integrated with the risk management plan. Identification of enabling/key technologies and components is complete. Prototype materials, tooling and test equipment, as well as personnel skills have been demonstrated on components in a production relevant environment, but many manufacturing processes and procedures are still in development. Manufacturing technology development efforts have been initiated or are | ▪ Has an industrial base assessment been initiated to identify potential manufacturing sources?<br>▪ Are lower level performance requirements sufficient to proceed to preliminary design?<br>▪ Has maturity been assessed on similar processes in production?<br>▪ Have manufacturing facilities been identified and plans been developed to produce prototypes? |

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| | | ongoing. Producibility assessments of key technologies and components are ongoing. A cost model has been constructed to assess projected manufacturing cost. | |
| 4 | Capability to produce the technology in a laboratory environment. | This level of readiness acts as an exit criterion for the Materiel Solution Analysis (MSA) Phase approaching a Milestone A decision. Technologies should have matured to at least TRL 4. This level indicates that the technologies are ready for the Technology Development Phase of acquisition. At this point, required investments, such as manufacturing technology development, have been identified. Processes to ensure manufacturability, producibility, and quality are in place and are sufficient to produce technology demonstrators. | ▪ Have industrial base capabilities been surveyed and known gaps/risks identified for preferred concept, key technologies, components, and/or key processes?<br>▪ Have form, fit, and function constraints been identified and manufacturing capabilities identified for preferred systems concepts?<br>▪ Has a survey to determine the current state of critical processes been completed?<br>▪ Has the availability of manufacturing facilities for prototype development and production been evaluated? |
| 3 | Manufacturing Proof of Concept Developed. | Manufacturing risks have been identified for building prototypes and mitigation plans are in place. Target cost objectives have been established and manufacturing cost drivers have been identified. Producibility assessments of design concepts have been completed. Key design performance parameters have been identified as well as any special tooling, facilities, material handling and skills required. | ▪ Have potential sources been identified for technology needs?<br>▪ Have top level performance requirements been defined?<br>▪ Have high level manufacturing processes been documented?<br>▪ Have specialized facility requirements/needs been identified? |
| 2 | Manufacturing Concepts Identified. | This level is characterized by describing the application of new manufacturing concepts. Applied research translates basic research into solutions for broadly defined military needs. Typically this level of readiness includes identification, paper studies and analysis of material and process approaches. An understanding of manufacturing feasibility and risk is emerging. | ▪ Have broad performance goals been identified that may drive manufacturing options?<br>▪ Have materials and/or process approaches been identified? |

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| 1 | Basic Manufacturing Implications Identified. | The focus is to address manufacturing shortfalls and opportunities needed to achieve program objectives. Basic research (i.e., funded by budget activity) begins in the form of studies. | ▪ Have manufacturing research opportunities been identified? |

Assign current MRL and provide rationale for rating in the table provided below.

| Technology | MRL | Rationale |
|---|---|---|
| | | |

## 6) Identification of Risks/Issues and Potential Mitigations

The risk should be stated in one clear and concise sentence, creating an "IF … THEN … MAY" statement. The details of the risk should include the Who, What, Where, When, Why, How and How Much of the risk. You should also consider what the impacts to the program are in terms of Cost, Schedule, and Performance if the risk becomes an issue. Please, rate the consequence C and likelihood L for each identified risk using the provided risk Tip Sheet for guidance.

Risk Mitigation Planning is the activity that identifies, evaluates, and selects options to set risk at acceptable levels given program constraints and objectives. It includes the specifics of what should be done, when it should be accomplished, who is responsible, and the funding and schedule tasks required to implement the risk mitigation plan (Risk Management Guide for DOD Acquisition, Sixth Edition, Version 1.0, August 2006 and Defense Acquisition Guidebook, Dated: August 5, 2010).

Identify risks/issues and, if known, potential mitigations in the table provided below.

| Technology | Risks | C | L | Mitigation |
|---|---|---|---|---|
| | | | | |

**TRL/IRL/MRL Mapping**

Provides a guide on how IRL and MRL generally map to TRL.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | A | | B | | C | | IOC | FOC |
| | **Materiel Solution Analysis** | **Technology Maturation & Risk Reduction** | | **Engineering & Manufacturing Development** | | **Production & Deployment** | | **Operations & Support** |
| | **Materiel Development Decision** | | **Post PDR Assessment** | | **Post CDR Assessment** | | **FRP Decision Review** | |
| **TRLs 1-3** Analytical/ Experimental Critical Function/ Characteristic Proof of Concept | **TRL 4** Component and/or Breadboard Validation in a Laboratory Environment | **TRL 5** Component and/or Breadboard Validation in a Relevant Environment | **TRL 6** System/ Subsystem Model or Prototype Demonstrated in a Relevant Environment | **TRL 7** System Prototype Demonstrated in an Operational Environment | | **TRL 8** Actual System Completed Qualified Through Test and Demonstration | **TRL 9** Actual System Mission Proven Through Successful Operations | **Technology Readiness Levels TRA Guidance April 2011** |
| **MRLs 1-3** Manufacturing Feasibility Assessed. Concepts Defined/ Developed | **MRL 4** Capability to Produce Technology in Lab Environment. Manufacturing Risks Identified | **MRL 5** Capability to Produce Prototype Components in a Production Relevant Environment | **MRL 6** Capability to Produce System/ Subsystem Prototypes in a Production Relevant Environment | **MRL 7** Capability to Produce Systems, Subsystems, or Components in a Production Representative Environment | **MRL 8** Pilot Line Capability Demonstrated. Ready for LRIP | **MRL 9** Low Rate Production Demonstrated. Capability in Place for FRP | **MRL 10** Full Rate Production Demonstrated. Lean Production Practices in Place | **Manufacturing Readiness Levels MRL Deskbook July 2011** |
| **IRLs 1-3** Interfaces Identified. Integration Proof of Concept. Integration Features Modeled | **IRL 4** Proposed Interfaces Established. Limited Functionality Demonstrated | **IRL 5** Major Integration Functions Demonstrated | **IRL 6** Integration Baseline Established. Platform Interfaces all Identified | **IRL 7** Full Prototype Integration Cis Successfully Integrated and have Functional Requirement Compliance | **IRL 8** Functionality of Integration Items Demonstrated in System Environment | **IRL 9** Integration Proven in Operational Test and Demonstration | | **Integration Readiness Levels Army Risk IPT** |

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# APPENDIX E – METHODOLOGY FOR SUPPORTING DATA SUFFICIENCY IN RISK ASSESSMENTS

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## METHODOLOGY FOR SUPPORTING DATA SUFFICIENCY IN RISK ASSESSMENTS

### Schedule Proportion Sampling Distribution

The Schedule Proportion Sampling Distribution (SPSD) uses Visual Basic and @Risk to compute a sampling distribution for the probability of meeting the PM's schedule. This algorithm uses Monte Carlo simulation, resampling methods such as parametric and non-parametric bootstrapping, KS Goodness of Fit testing, Q-Q plotting, and other mathematical tools. This method produces a large number of estimates for P. At least 500 simulation runs (denoted at 500 +) are required for stable results.

### Percentile CI with Bias Correction

Section 6.5.2.2 references CI and coverage concept material from: Nierwinski, J., "MAINTAINABILITY DATA DECISION METHODOLOGY (MDDM)", AMSAA TR-2011-19, June 2011.

Let's apply the Bias Corrected (BC) method to this distribution of 500 estimates of P. The BC method is basically an adjustment (for non-normal data) to the percentile points of the Percentile Method. The "BC" adjusts these percentile points when the mean and median are not equal – hence it tries to normalize the distribution.

Let $\hat{P}^{(\alpha_s)}, \hat{P}^{(1-\alpha_s)}$ indicate the 100* $\alpha_s$ th and 100*($1-\alpha_s$)th percentiles from the 500 estimates of P. This represents the percentile method for a 2-sided 100*(1-2$\alpha_s$) CI. The lower and upper bound using the BC method is given by:

$\hat{P}^{(\alpha_1)}$, where $\alpha_1 = \Phi(2\hat{z}_{\mathbf{0}} + z^{(\alpha_s)})$ ; Lower Bound

$\hat{P}^{(\alpha_2)}$, where $\alpha_2 = \Phi(2\hat{z}_{\mathbf{0}} + z^{(1-\alpha_s)})$ ; Upper Bound

Here $\Phi(*)$ is the standard normal cumulative distribution function and $z^{(1-\alpha_s)}$ is the 100* $(1-\alpha_s)$ th percentile point of a standard normal distribution. For example $z^{(.95)}$ = 1.645 and $\Phi(1.645)$ = .95.

The value of BC is derived by the proportion of replications that is less than the original estimate $\hat{P}$. Here is that value:

$$\hat{z}_0 = \Phi^{-1}\left(\frac{\#\{\hat{MR}_b < \hat{MR}\}}{B = 500+}\right)$$

In order to accurately build this 2-sided CI stochastic model, we need to assure that the sample has enough data to achieve the requested level of confidence. To validate this accuracy we use coverage models.

First let's define what we mean by coverage and accuracy. Coverage is defined to be the percentage of CIs that contain than the true population parameter P, where each CI is constructed with some method at the 100*($1-\alpha_s$)th confidence level for a given random sample of n analogous programs. In other words, we need to run the inference method (Monte Carlo simulation with BC method) 500+ times (500+ samples drawn from a parametric or nonparametric population) to obtain 500+ inferences (i.e. 500+ UB's). These 500+ samples are not to be confused with the B (500+) iterations from the Monte Carlo simulation with BC method. Note, the 500+ simulated populations are built based on the sample information. Then we determine how many CIs contain the true P.

Accuracy is just a convergence rule for explaining the relative error of a 1-sided coverage. The rule focuses on the speed at which the relative error approaches 0. Second order accuracy is defined as the actual non-coverage probability intended to be $\alpha_s$% for a 1-sided $(1-\alpha_s)$% CI, approaches the ideal of $\alpha_s$% with error proportional to 1/n. First order accuracy would approach the ideal of $\alpha_s$% with error proportional to $\frac{1}{\sqrt{n}}$. This means that the relative error of the 1-sided coverage is of the order O(1/n) for second-order accuracy and O($\frac{1}{\sqrt{n}}$) for first-order accuracy. BC is 2$^{nd}$ order accurate since it adjusts the percentile points based on the non-normal data. The percentile method is only 1$^{st}$ order accurate since it does not make any adjustments to the percentile points.

Lessons learned from a coverage validation study reveal the following results:

- At least 6 analogous programs (n) are needed to perform any of these confidence interval methods.
- If the probability is extreme (near 0 or 1) then use the Wilson Score Interval.
- If the probability is not extreme then use one of the two Monte Carlo methods:
    - Use Percentile Method if n is 10 or less.
    - Use Bias Correction Method if n > 10.

Lessons learned demonstrated that both empirical and best fitting distribution techniques yielded similar coverage's. Hence, choose the smallest CI width when selecting between these two techniques.

## Error Tolerance

The decision maker (DM) must decide an acceptable and tolerable width of the CI. The assessment of the “tolerance of width of the CI” is a decision problem which requires proper consideration of what happens to the “big picture problem” if the endpoints of this CI (namely the UB and LB) are truly realized. In other words, the DM may change the decision as a result of the LB or UB occurring. If the decision is changed, then the sensitivity of this width is too large and cannot be tolerated. Hence, the width needs to be smaller. In order to reduce the width, more analogous data needs to be collected.

On the other hand, if the DM does not change the decision as result of this width then the width is acceptable or tolerated, and enough data was collected. Keep in mind that different problems have different sensitivities to CI width. Sometimes a probability of 90% vs. 70% of meeting schedule will not change the overall alternative level decision (i.e. both are directionally pretty good with low risk). However, a probability of 99% vs. 90% of a bridge breaking in the next year could be a decision changer.

For schedule risk assessment applications, the main concern that the decision maker has is on the LB because that is where the risk is contained. Therefore, the risk is greater when a large width exists between the mean and the LB probabilities compared to the UB. The DM needs to assess the largest width (mean to LB) that he or she can live with. In other words, when does the length of the width become an issue or when does it cause the DM to re-consider his or her decision.

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# APPENDIX F – DATA ALLOCATION ISSUES

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## DATA ALLOCATION ISSUES

Suppose historical analogous programs from MS B-to-MS C were collected and this data really represented MS A-to-MS C. For example, the programs may have prematurely entered the acquisition process at MS B when the technology readiness levels were actually lower than claimed. This could result in MS A to MS B activities being performed during MS B-to-MS C. An algorithm was designed to allocate some of the time collected in MS B-to-MS C back to MS A-to-MS B. To do this, historical analogous programs are collected that have both phases and a weighted average factor is computed to be applied to the time in MS B-to-MS C. This will shift some time back to MS A-to-MS B.

This weighted average factor is based on the history of analogous programs with times in both phases and is only an estimate. Every estimate based on data has a CI associated with it. So, a CI on the factor estimate is computed and then all models are reallocated and re-run using the mean estimate and the lower and upper bounds from the CI.

Confidence Intervals for Ratio Means (CIM4RM) are used to compute the CI because this metric is a ratio mean. The USPTO published patent reference for CIM4RM is listed below:

Pub. No. : U.S.2011/0054839A1
Pub. Date : March 3, 2011
Inventor: John Nierwinski

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